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[54] **METHOD AND APPARATUS FOR SUPPORTING AND FOR SUPPLYING THERAPY TO A PATIENT**

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[52] **U.S. Cl.** **5/713**; 5/915; 5/715; 5/710

[58] **Field of Search** 5/615, 915, 710, 5/711, 712, 713, 714, 715, 911

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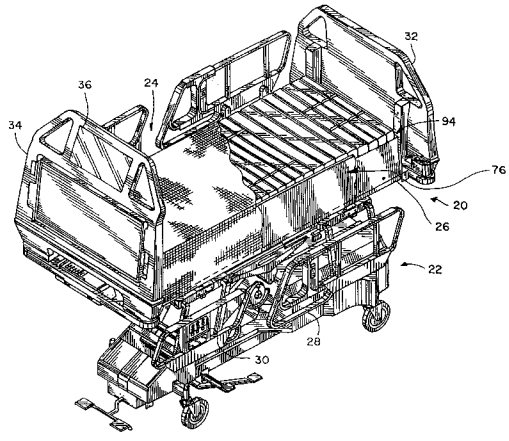
[57] **ABSTRACT**

An apparatus is provided which supports a patient on an inflatable structure. The inflatable structure preferably has two components: a) lower inflatable layer which is selectively operable to provide basic support for the patient and which includes a plurality of laterally offset zone which may be independently inflatable to control rotation of the patient. Further, a second inflatable layer includes a plurality of zones for establishing optimal patient interface pressures and patient comfort levels, and may also include sufficiently independent inner chambers to facilitate the providing of specific therapies such as alternation of primary pressure contact areas, or percussion or vibration of the patient through inner cell inflation.

5 Claims, 34 Drawing Sheets



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Advertisement, "Home Kair D.M.S. Dynamic Mattress System," *Kinetic Concepts, Inc.,* Aug. 1993.

Brochure, "AkroTech 4000T," *Lumex* © 1994, Oct. 1994.

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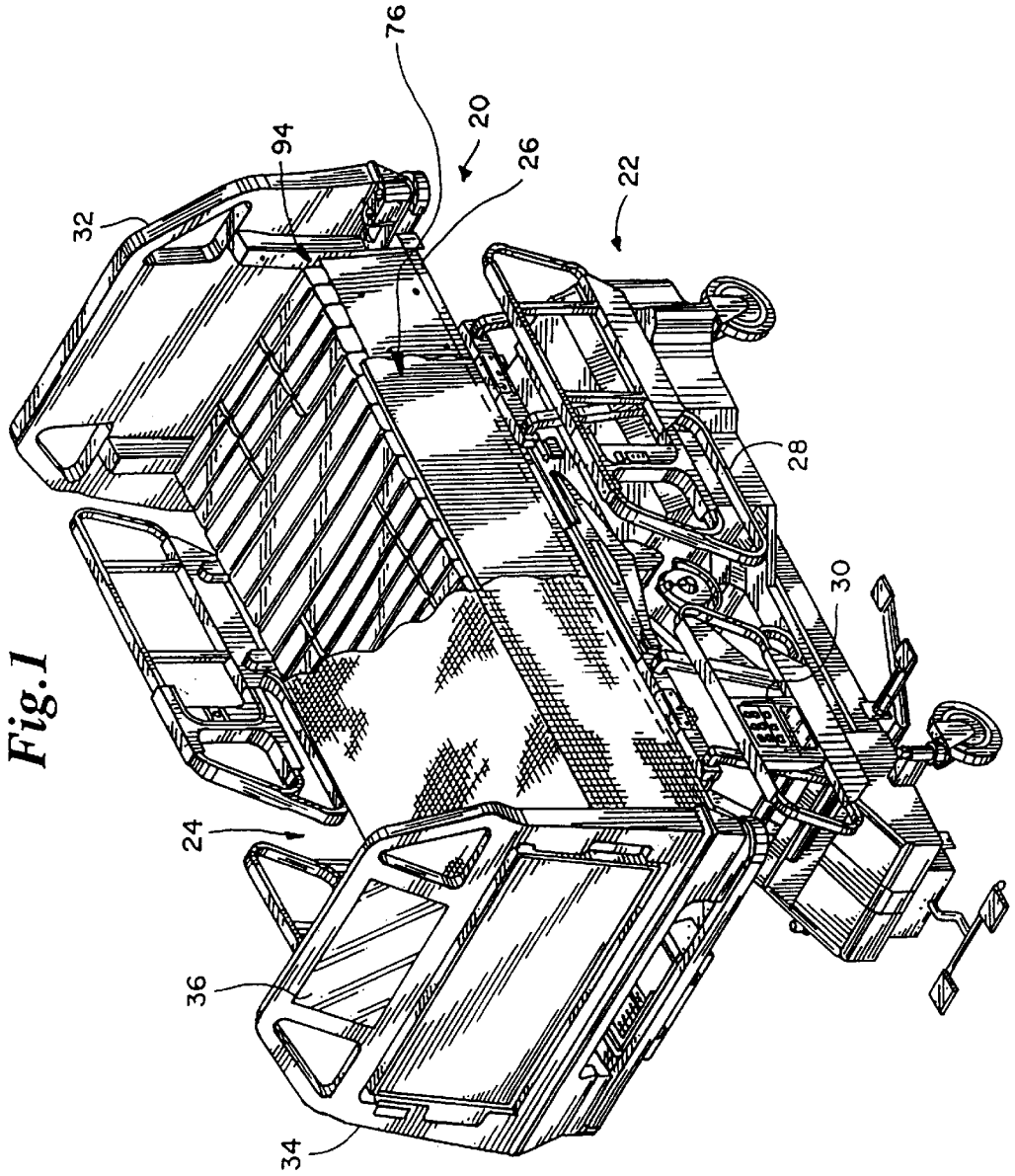


Fig. 1

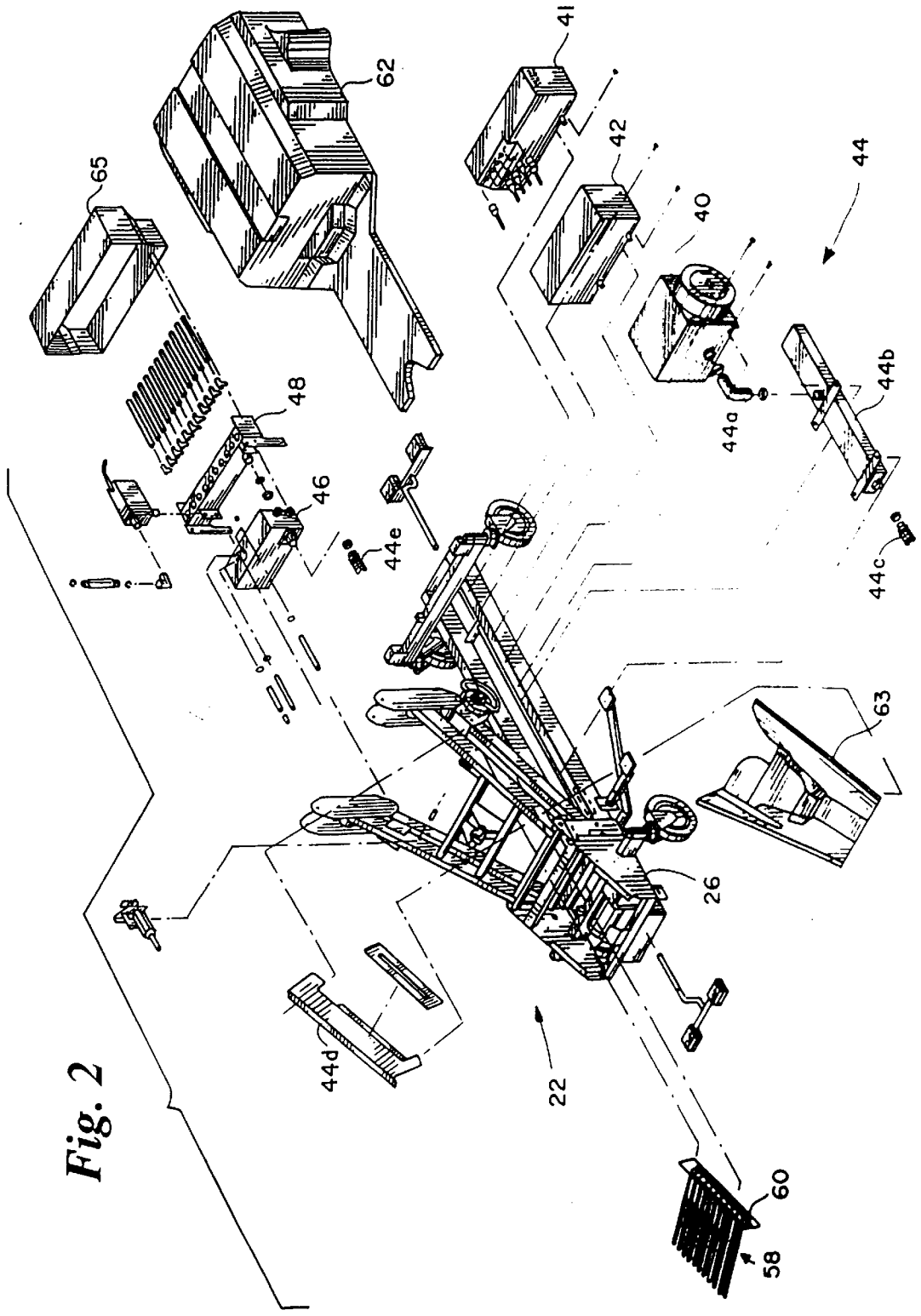
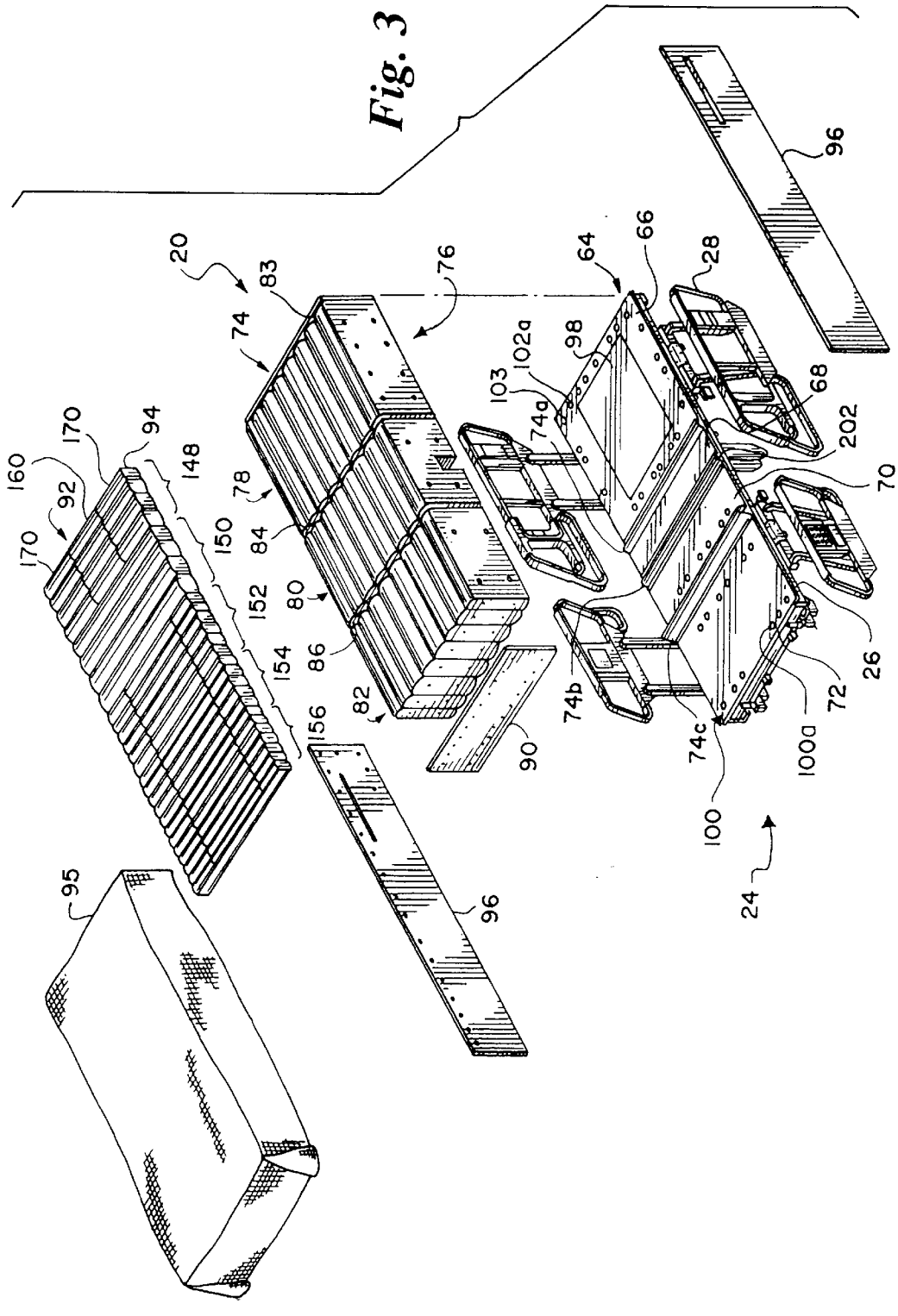


Fig. 2

Fig. 3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83
74
76
64
66
28
96
98
102a
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74a
68
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70
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90
74b
74c
72
100a
100
26
24
95
96

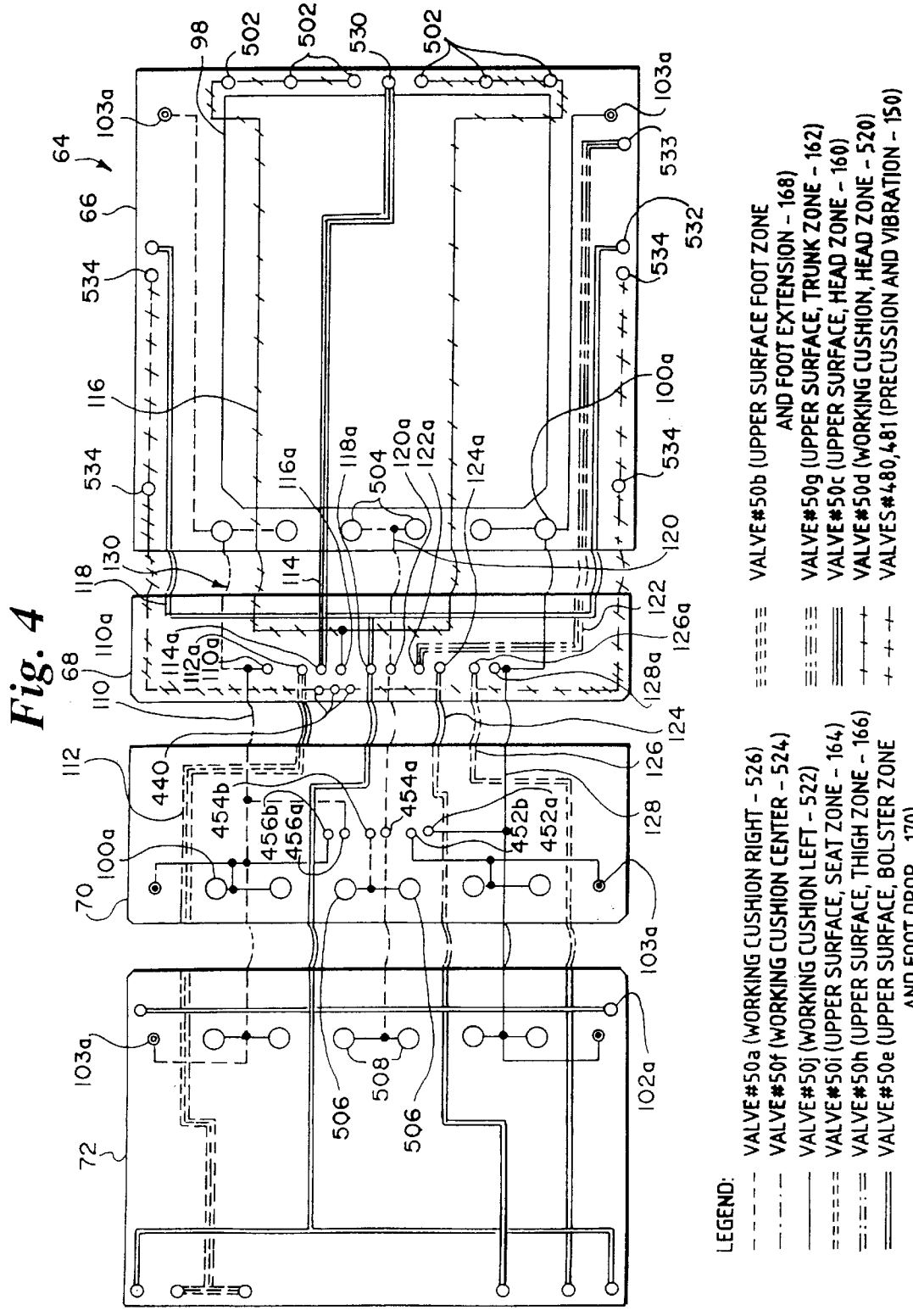
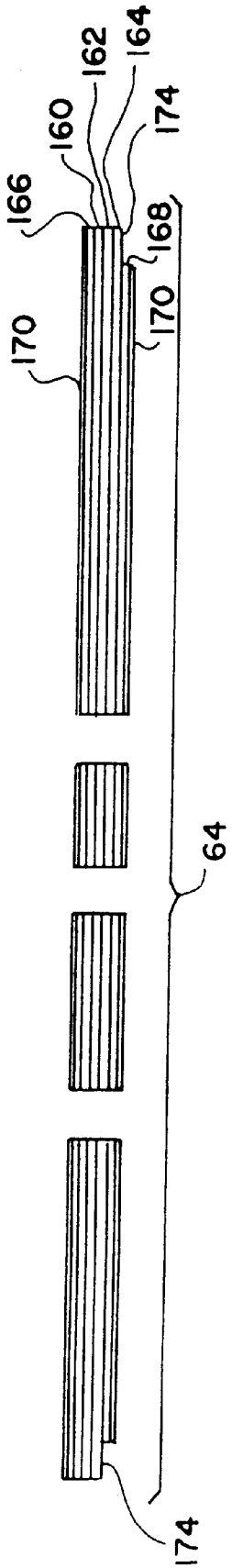

LEGEND:
VALVE#50a (WORKING CUSHION RIGHT - 526)
VALVE#50f (WORKING CUSHION CENTER - 524)
VALVE#50j (WORKING CUSHION LEFT - 522)
VALVE#50i (UPPER SURFACE, SEAT ZONE - 164)
VALVE#50h (UPPER SURFACE, THIGH ZONE - 166)
VALVE#50e (UPPER SURFACE, BOLSTER ZONE AND FOOT DROP - 170)
VALVE#50b (UPPER SURFACE FOOT ZONE AND FOOT EXTENSION - 168)
VALVE#50g (UPPER SURFACE, TRUNK ZONE - 162)
VALVE#50c (UPPER SURFACE, HEAD ZONE - 160)
VALVE#50d (WORKING CUSHION, HEAD ZONE - 520)
VALVES#480,481 (PRECUSSION AND VIBRATION - 150)

Fig. 4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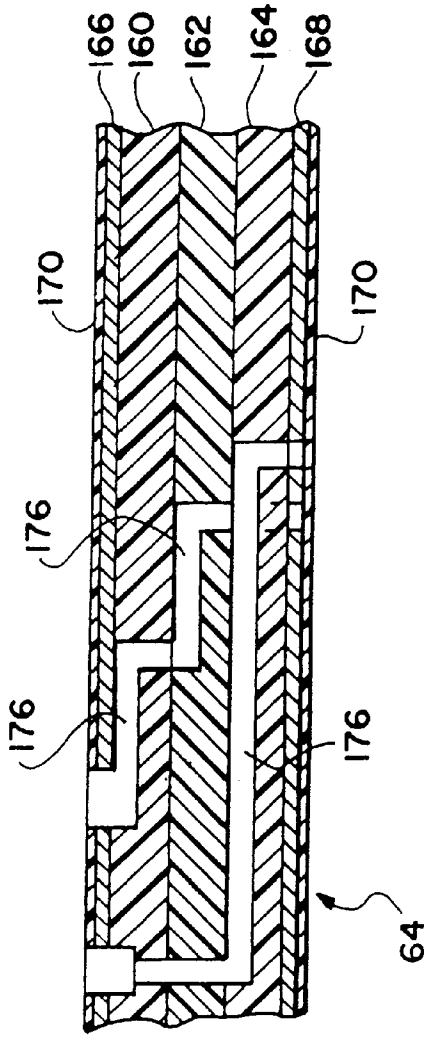
162
164
174
168
170
170
64
174

Fig. 5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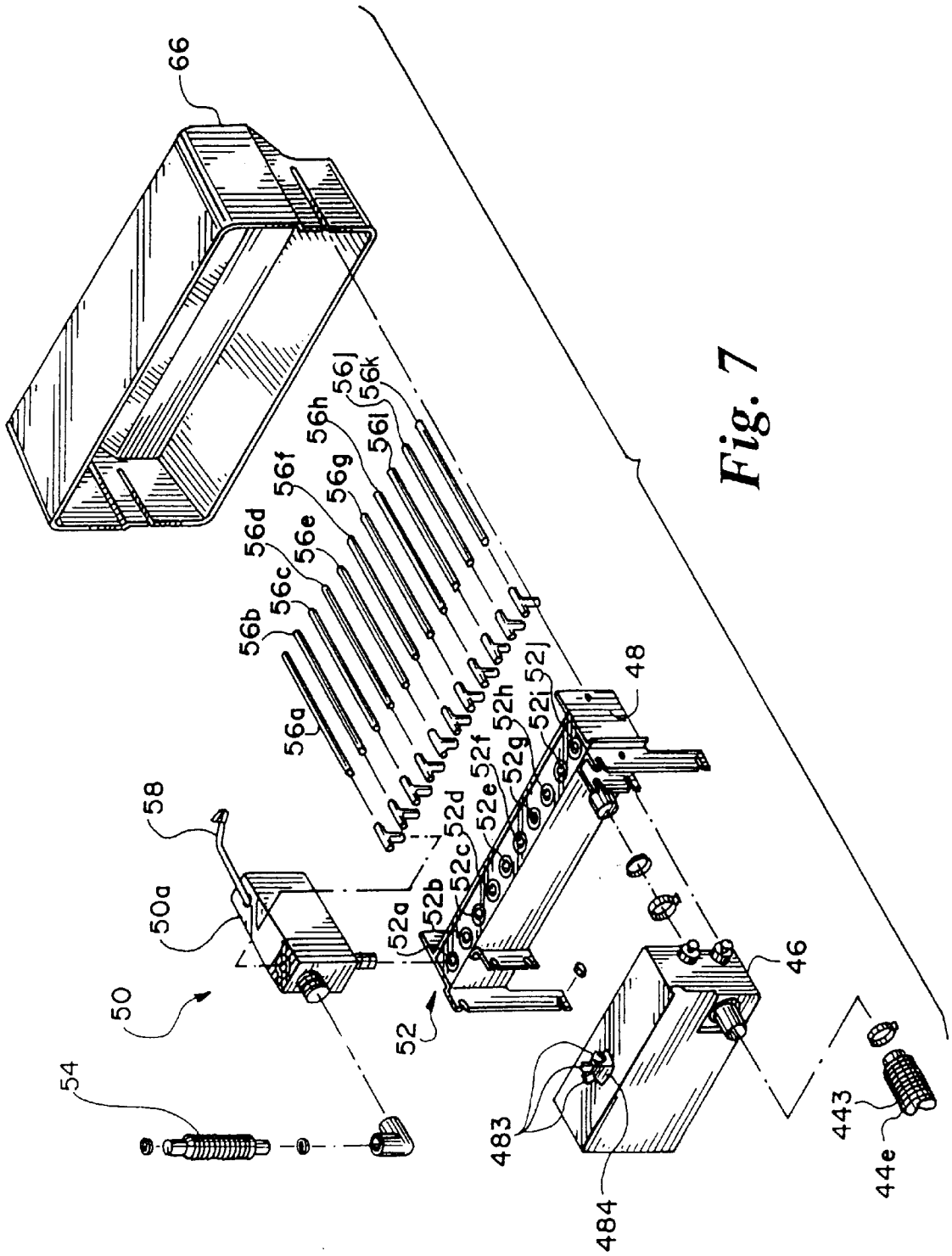
176
64

Fig. 6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56l
56k
56h
56g
56f
56e
56d
56c
56b
56a
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52j
52i
52h
52g
52f
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52d
52c
52b
52a
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50a
50
52
54
46
483
484
443
44e

Fig. 7

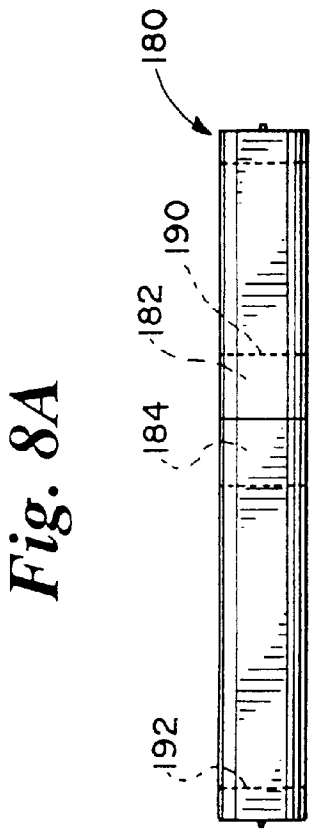


Fig. 8A

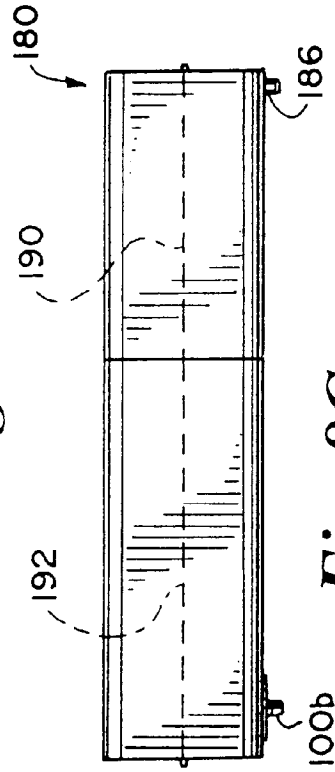


Fig. 8B

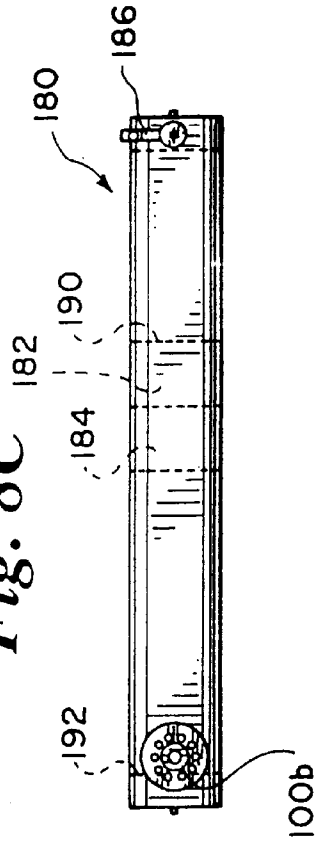


Fig. 8C

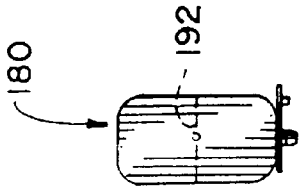


Fig. 8D

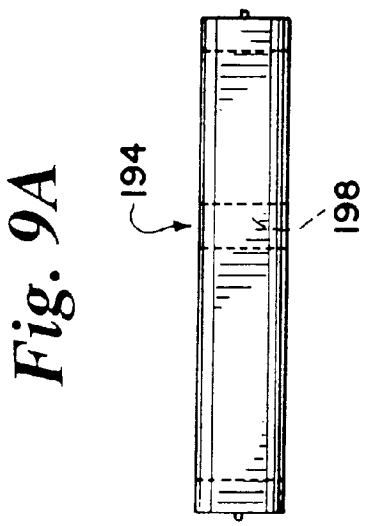


Fig. 9A

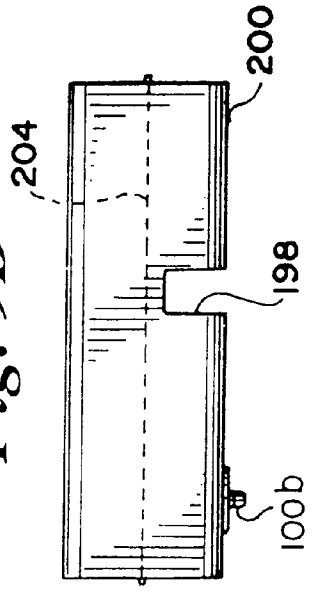


Fig. 9B

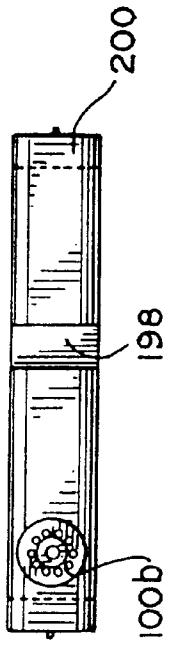


Fig. 9C

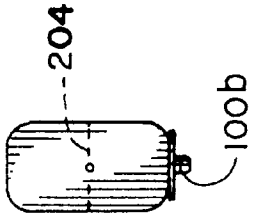


Fig. 9D

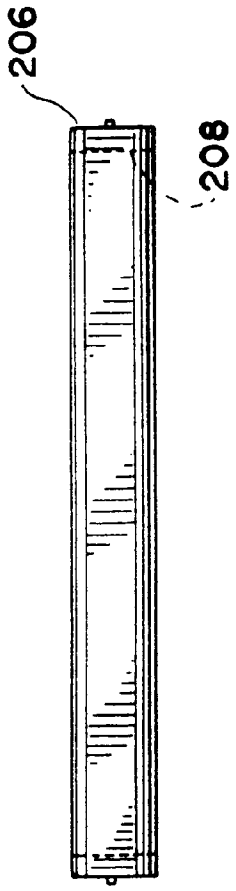


Fig. 10A

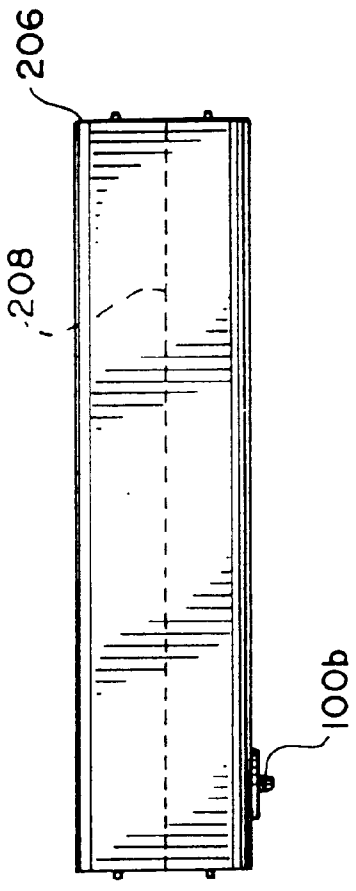


Fig. 10B

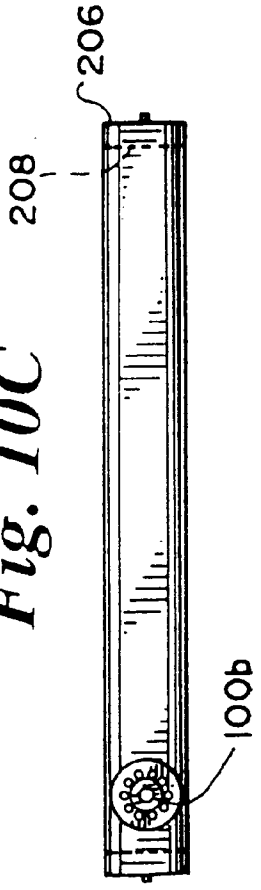


Fig. 10C

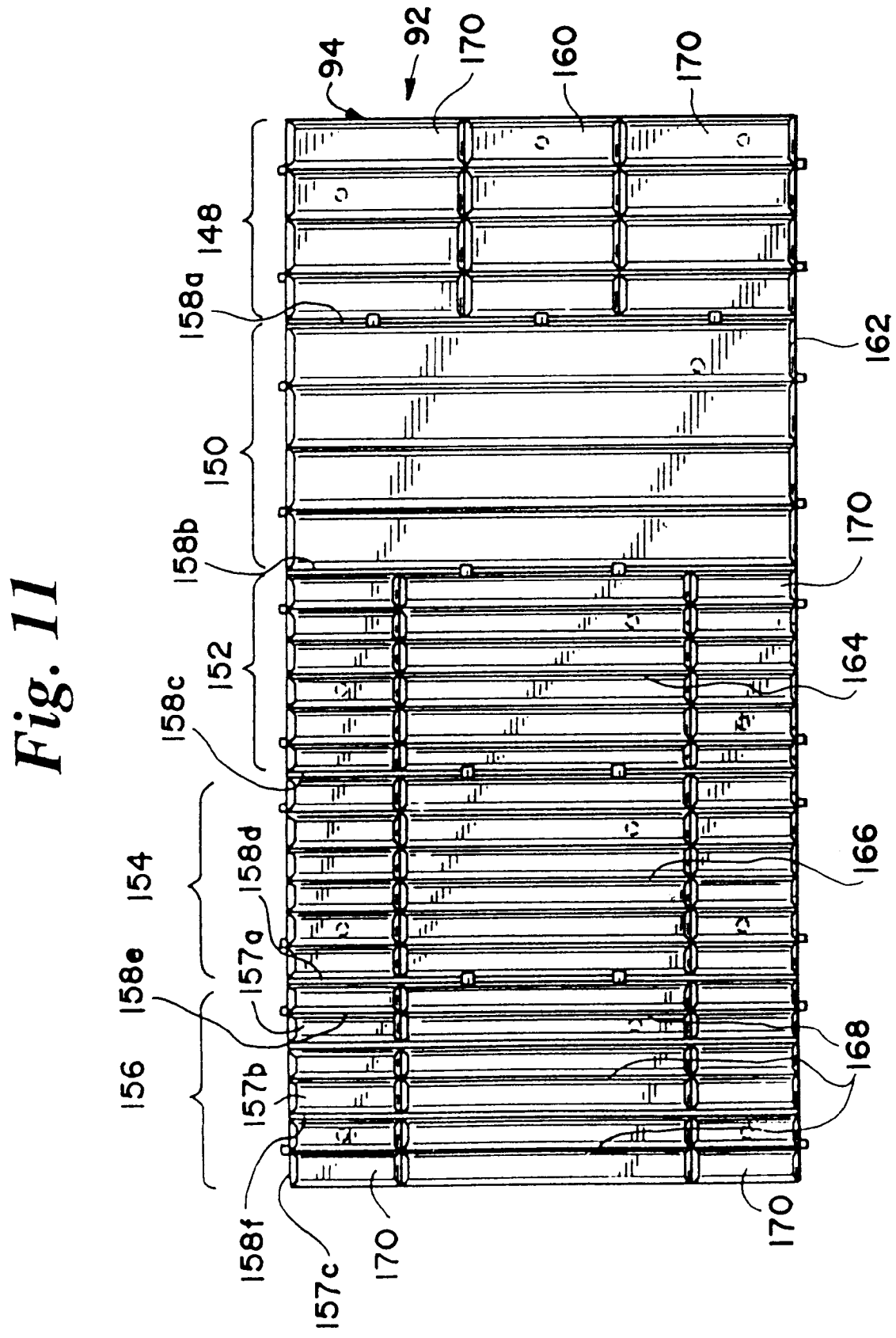

94
92
170
160
170
148
158a
162
150
158b
170
152
164
158c
154
158d
166
157a
158e
168
156
157b
158f
157c
170
170

Fig. 11

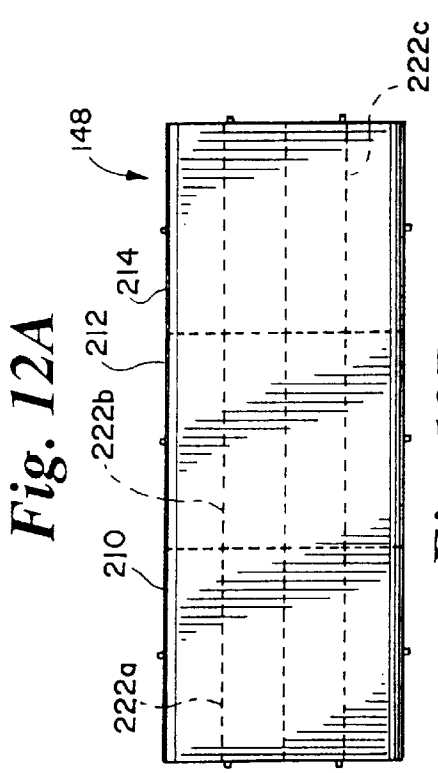


Fig. 12A

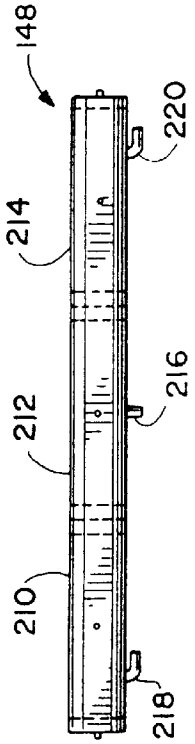


Fig. 12B

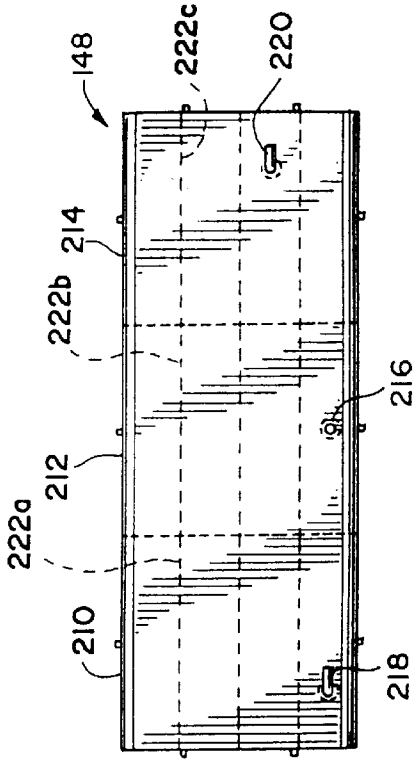


Fig. 12C

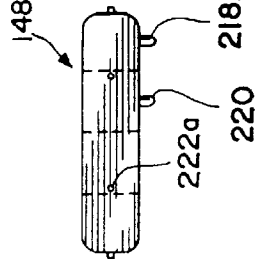


Fig. 12D

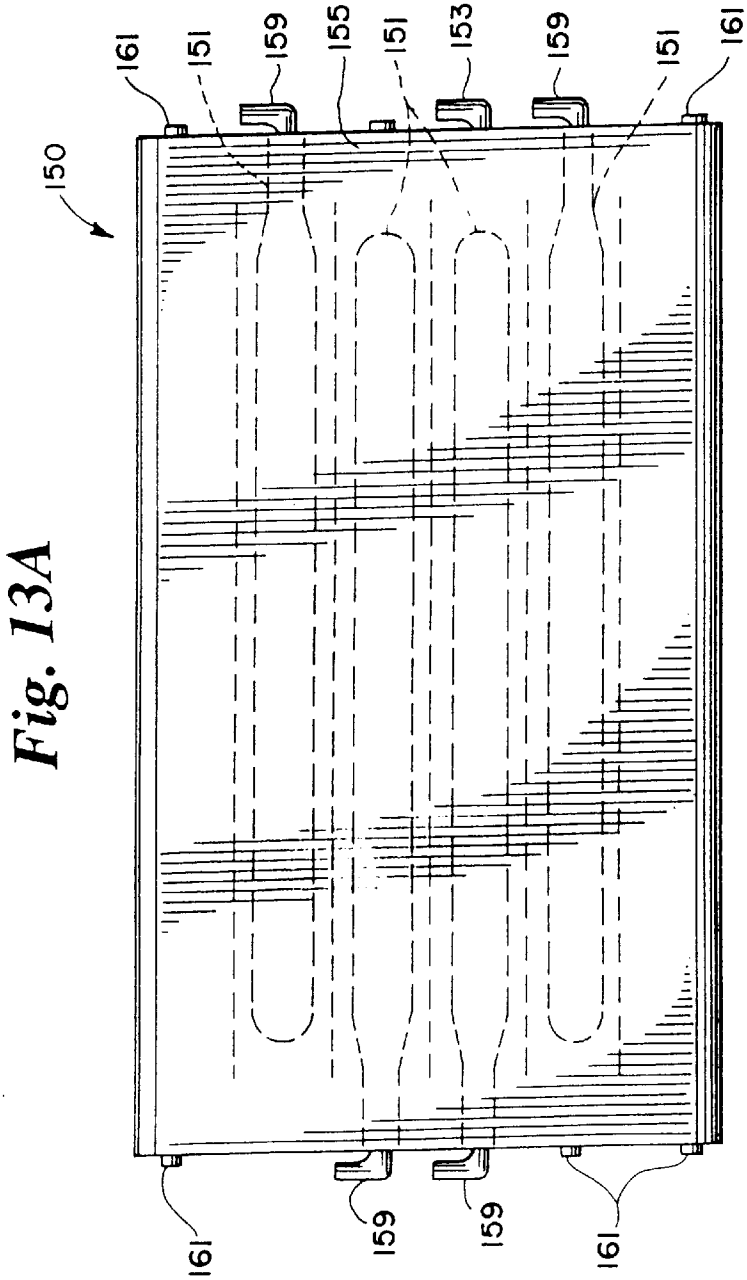


Fig. 13A

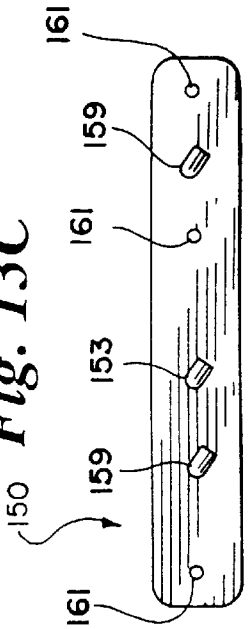


Fig. 13C

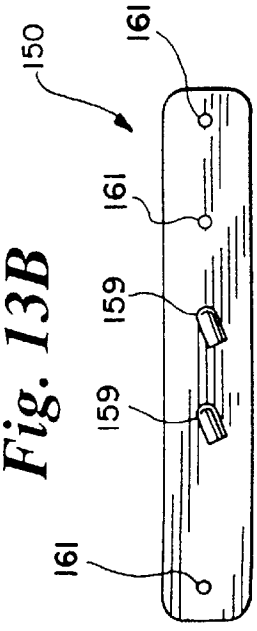


Fig. 13B

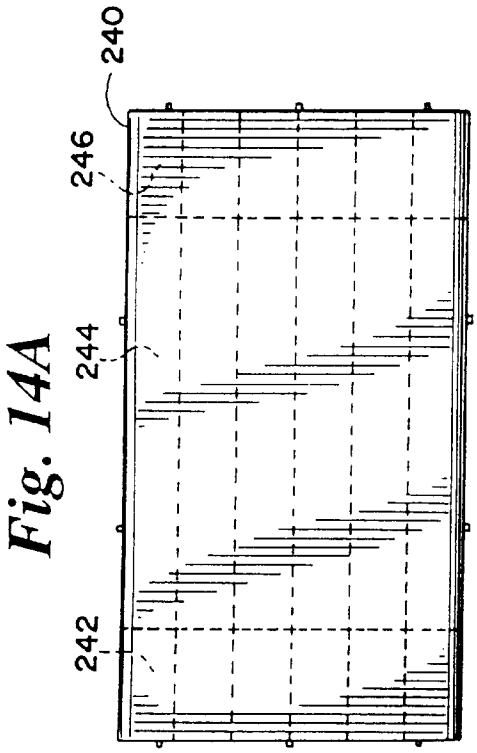


Fig. 14A

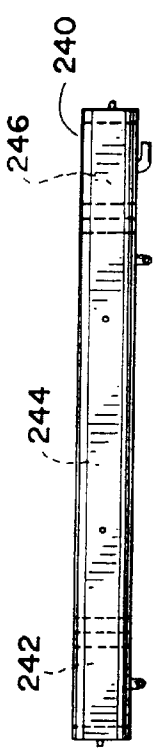


Fig. 14B

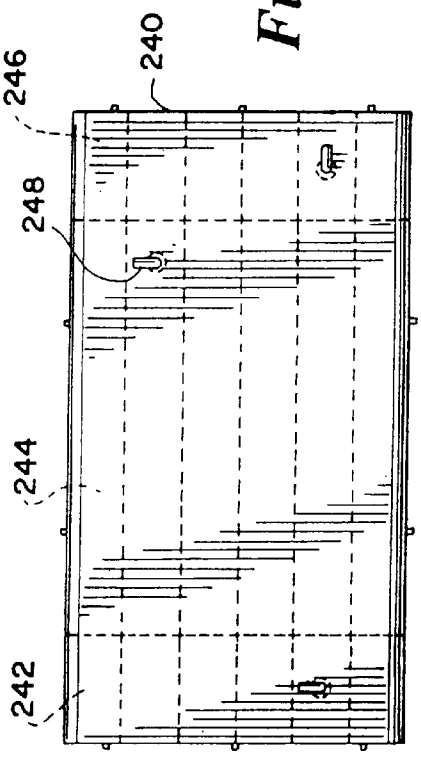


Fig. 14C

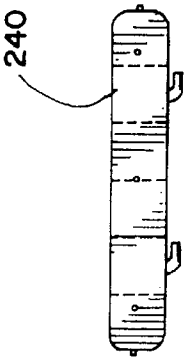


Fig. 14D

Fig. 15D

Fig. 15A

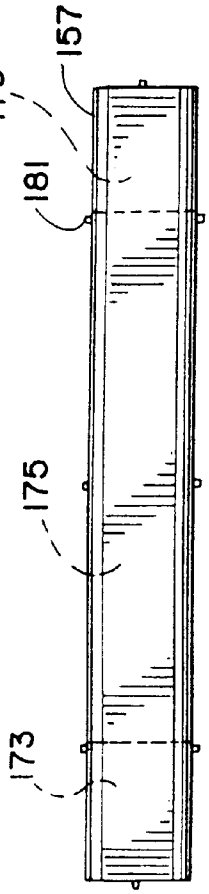


Fig. 15B

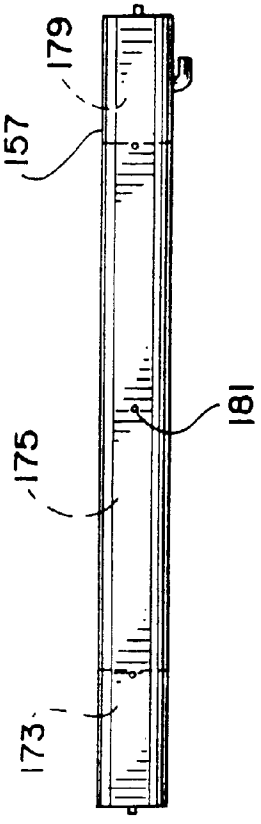
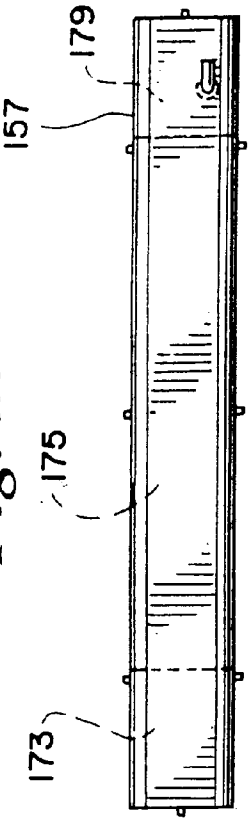


Fig. 15C



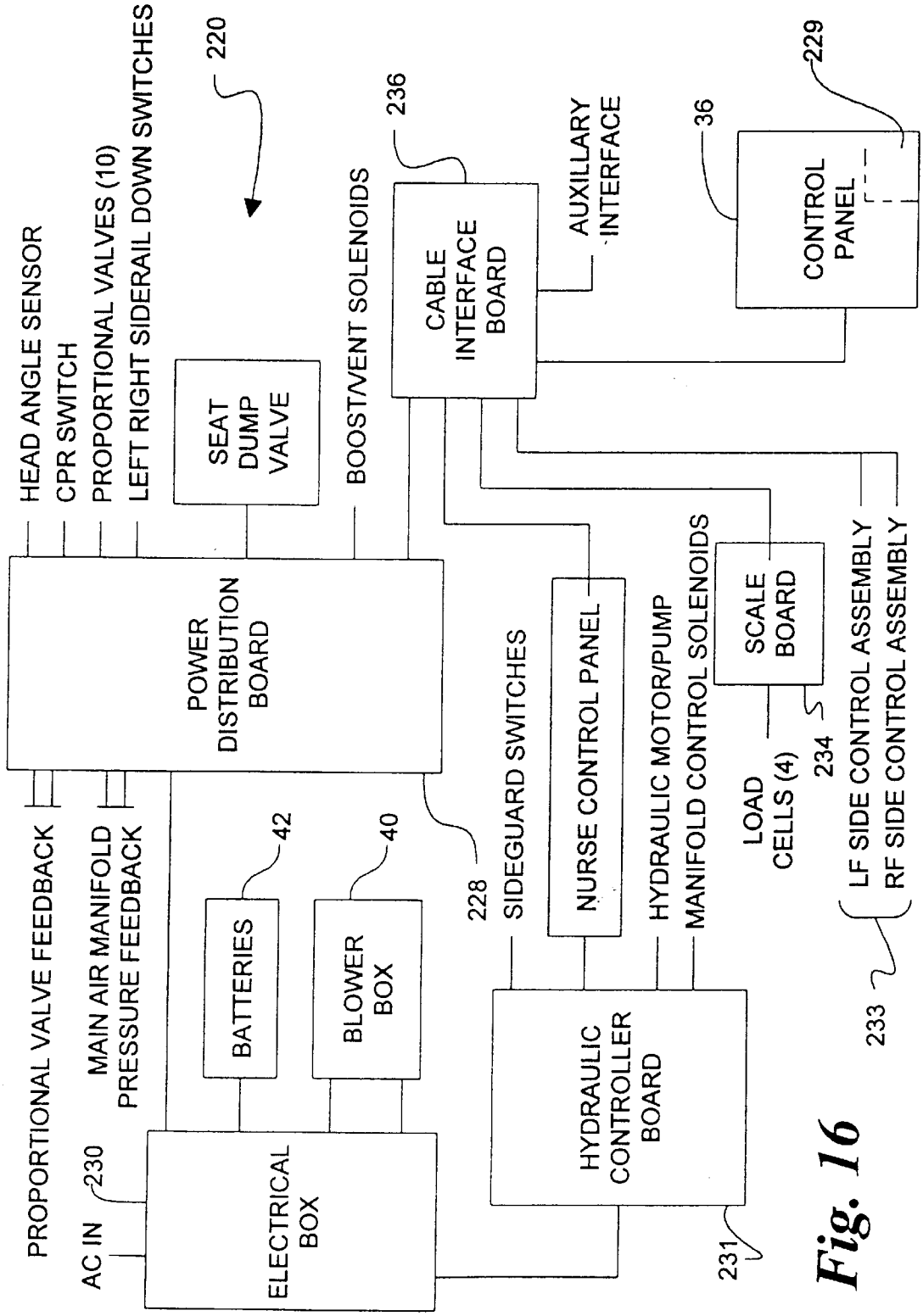

HEAD ANGLE SENSOR
CPR SWITCH
PROPORTIONAL VALVES (10)
LEFT RIGHT SIDERAIL DOWN SWITCHES
220
SEAT DUMP VALVE
BOOST/VENT SOLENOIDS
236
CABLE INTERFACE BOARD
AUXILLARY INTERFACE
36
CONTROL PANEL
229
POWER DISTRIBUTION BOARD
PROPORTIONAL VALVE FEEDBACK
MAIN AIR MANIFOLD PRESSURE FEEDBACK
42
BATTERIES
40
BLOWER BOX
228
SIDEGUARD SWITCHES
NURSE CONTROL PANEL
HYDRAULIC MOTOR/PUMP MANIFOLD CONTROL SOLENOIDS
SCALE BOARD
LOAD CELLS (4)
234
LF SIDE CONTROL ASSEMBLY
RF SIDE CONTROL ASSEMBLY
233
AC IN
230
ELECTRICAL BOX
HYDRAULIC CONTROLLER BOARD
231

Fig. 16

Fig. 17

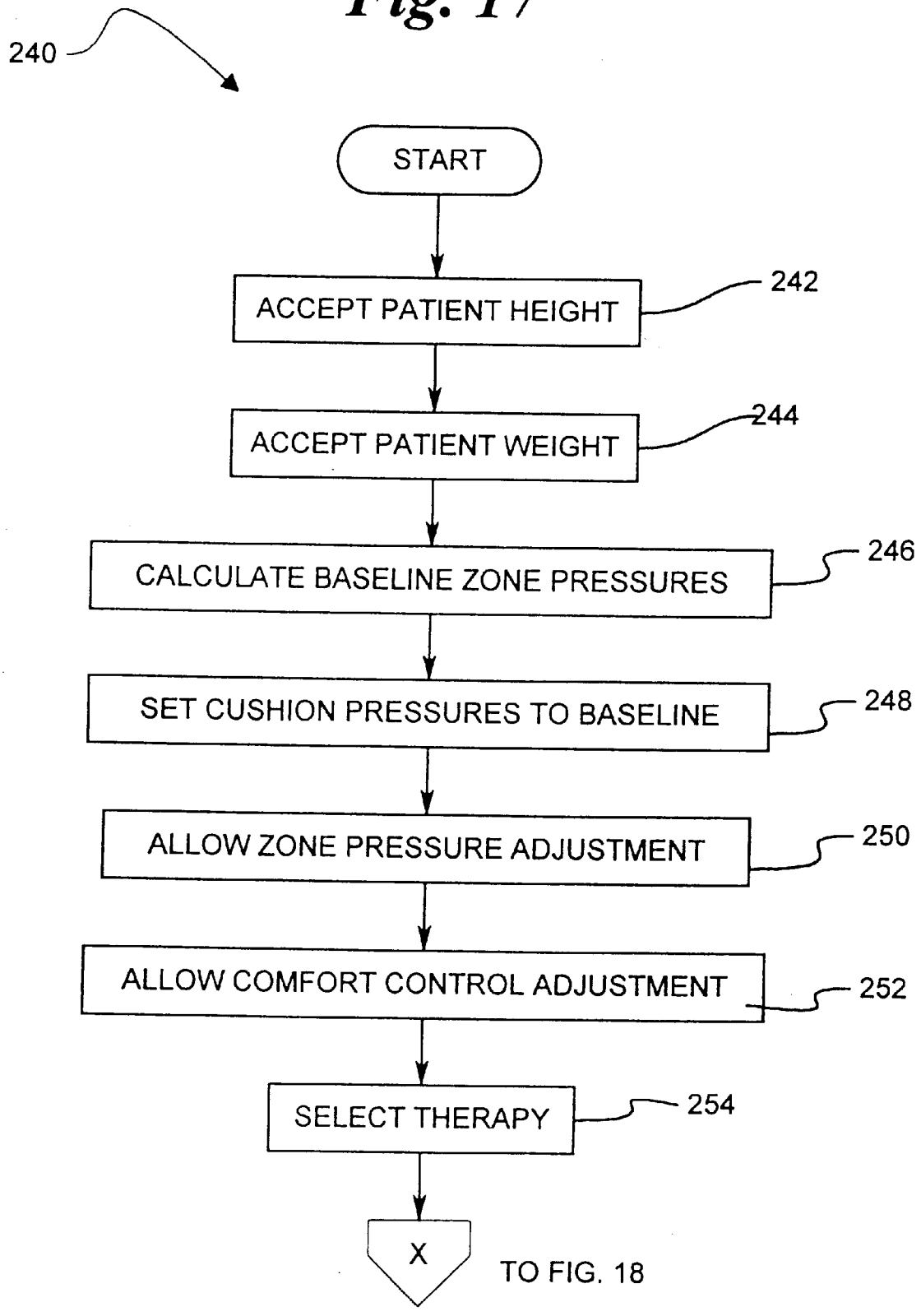
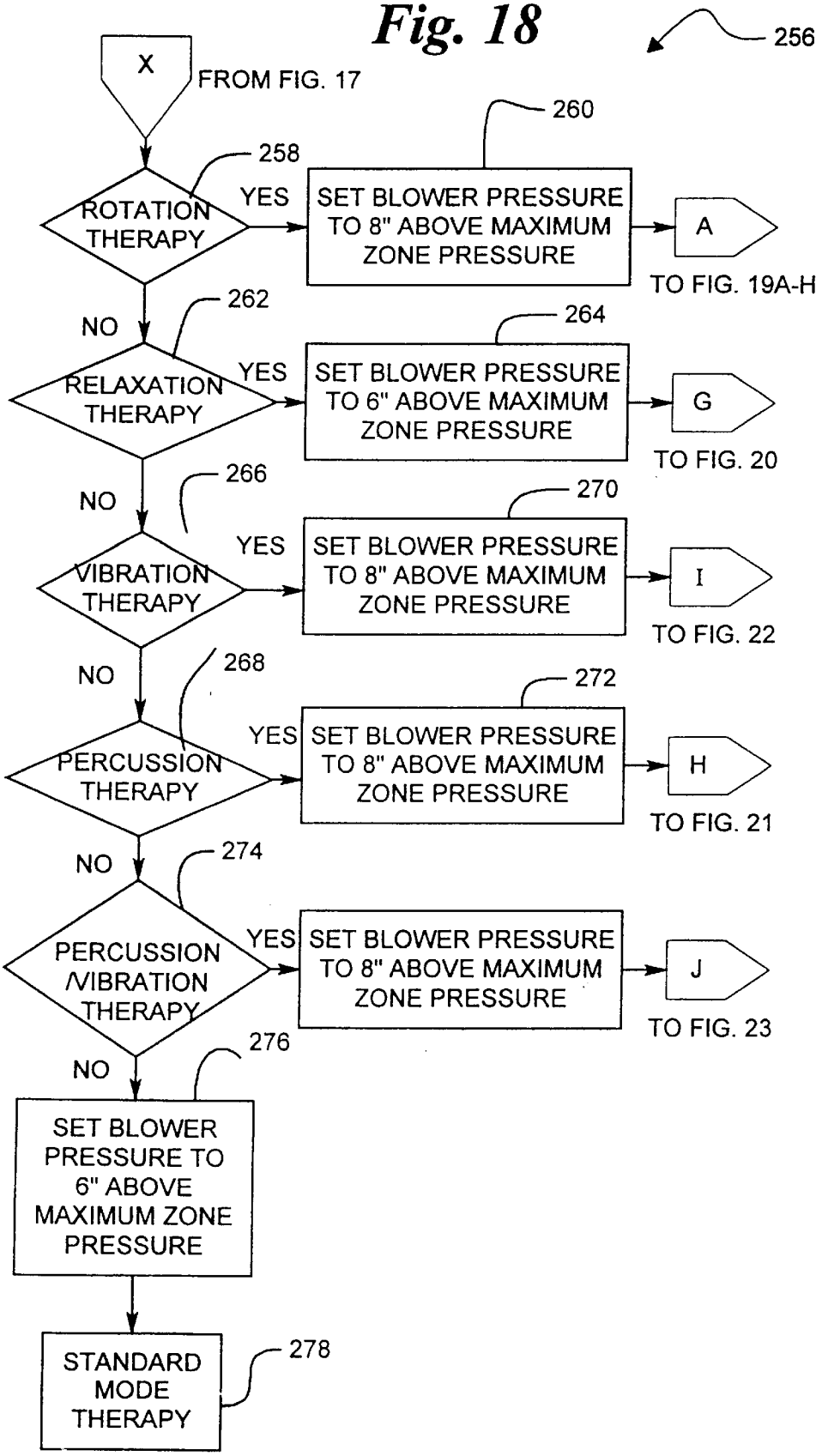

240
START
ACCEPT PATIENT HEIGHT
242
ACCEPT PATIENT WEIGHT
244
CALCULATE BASELINE ZONE PRESSURES
246
SET CUSHION PRESSURES TO BASELINE
248
ALLOW ZONE PRESSURE ADJUSTMENT
250
ALLOW COMFORT CONTROL ADJUSTMENT
252
SELECT THERAPY
254
X
TO FIG. 18

Fig. 18


256
X
FROM FIG. 17
258
ROTATION THERAPY
YES
260
SET BLOWER PRESSURE TO 8" ABOVE MAXIMUM ZONE PRESSURE
A
TO FIG. 19A-H
NO
262
RELAXATION THERAPY
YES
264
SET BLOWER PRESSURE TO 6" ABOVE MAXIMUM ZONE PRESSURE
G
TO FIG. 20
NO
266
VIBRATION THERAPY
YES
270
SET BLOWER PRESSURE TO 8" ABOVE MAXIMUM ZONE PRESSURE
I
TO FIG. 22
NO
268
PERCUSSION THERAPY
YES
272
SET BLOWER PRESSURE TO 8" ABOVE MAXIMUM ZONE PRESSURE
H
TO FIG. 21
NO
274
PERCUSSION /VIBRATION THERAPY
YES
SET BLOWER PRESSURE TO 8" ABOVE MAXIMUM ZONE PRESSURE
J
TO FIG. 23
NO
276
SET BLOWER PRESSURE TO 6" ABOVE MAXIMUM ZONE PRESSURE
STANDARD MODE THERAPY
278

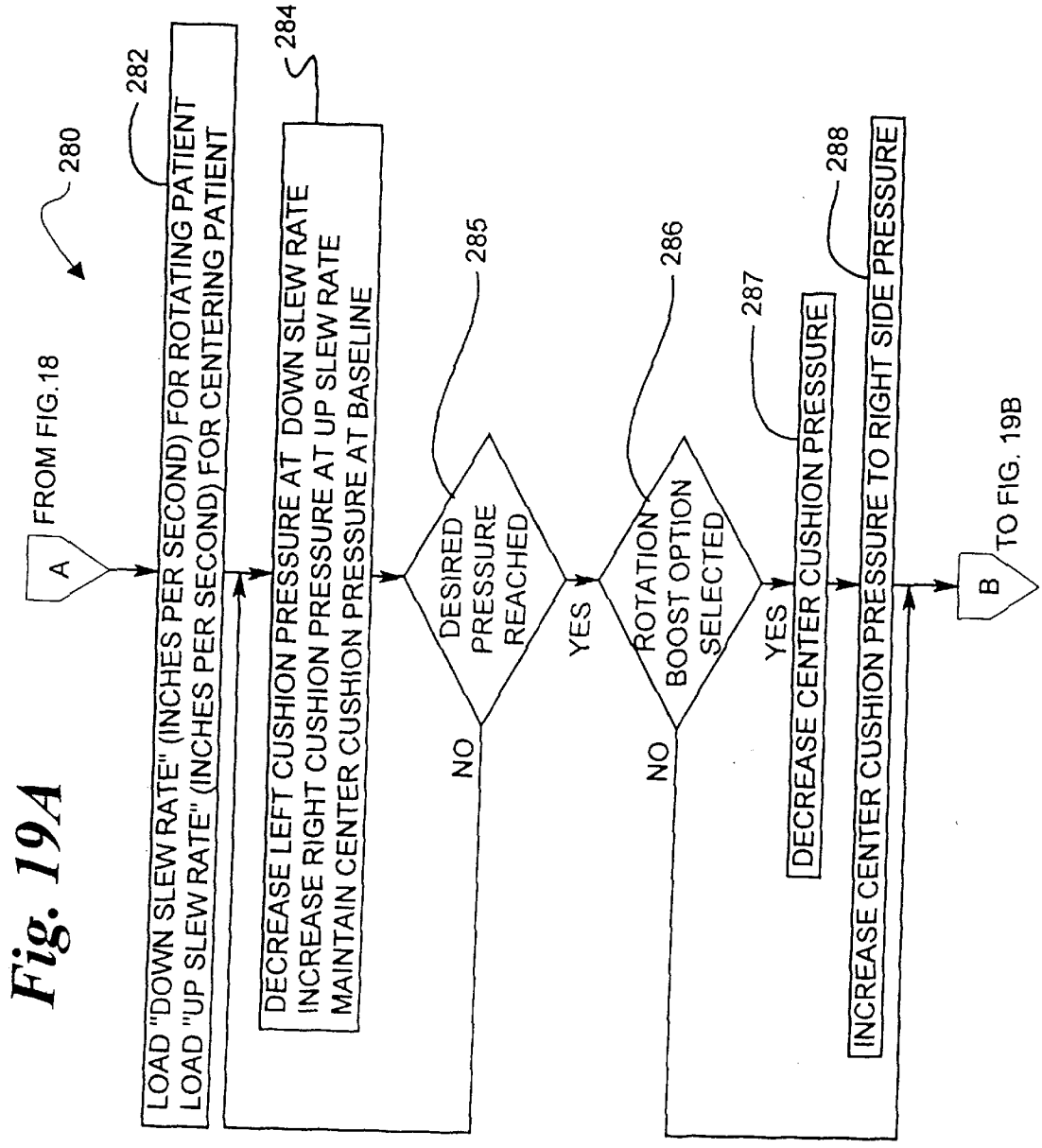

FROM FIG. 18
A
280
282
LOAD "DOWN SLEW RATE" (INCHES PER SECOND) FOR ROTATING PATIENT
LOAD "UP SLEW RATE" (INCHES PER SECOND) FOR CENTERING PATIENT
284
DECREASE LEFT CUSHION PRESSURE AT DOWN SLEW RATE
INCREASE RIGHT CUSHION PRESSURE AT UP SLEW RATE
MAINTAIN CENTER CUSHION PRESSURE AT BASELINE
285
DESIRED PRESSURE REACHED
NO
YES
286
ROTATION BOOST OPTION SELECTED
NO
YES
287
DECREASE CENTER CUSHION PRESSURE
288
INCREASE CENTER CUSHION PRESSURE TO RIGHT SIDE PRESSURE
B
TO FIG. 19B

Fig. 19A

Fig. 19B

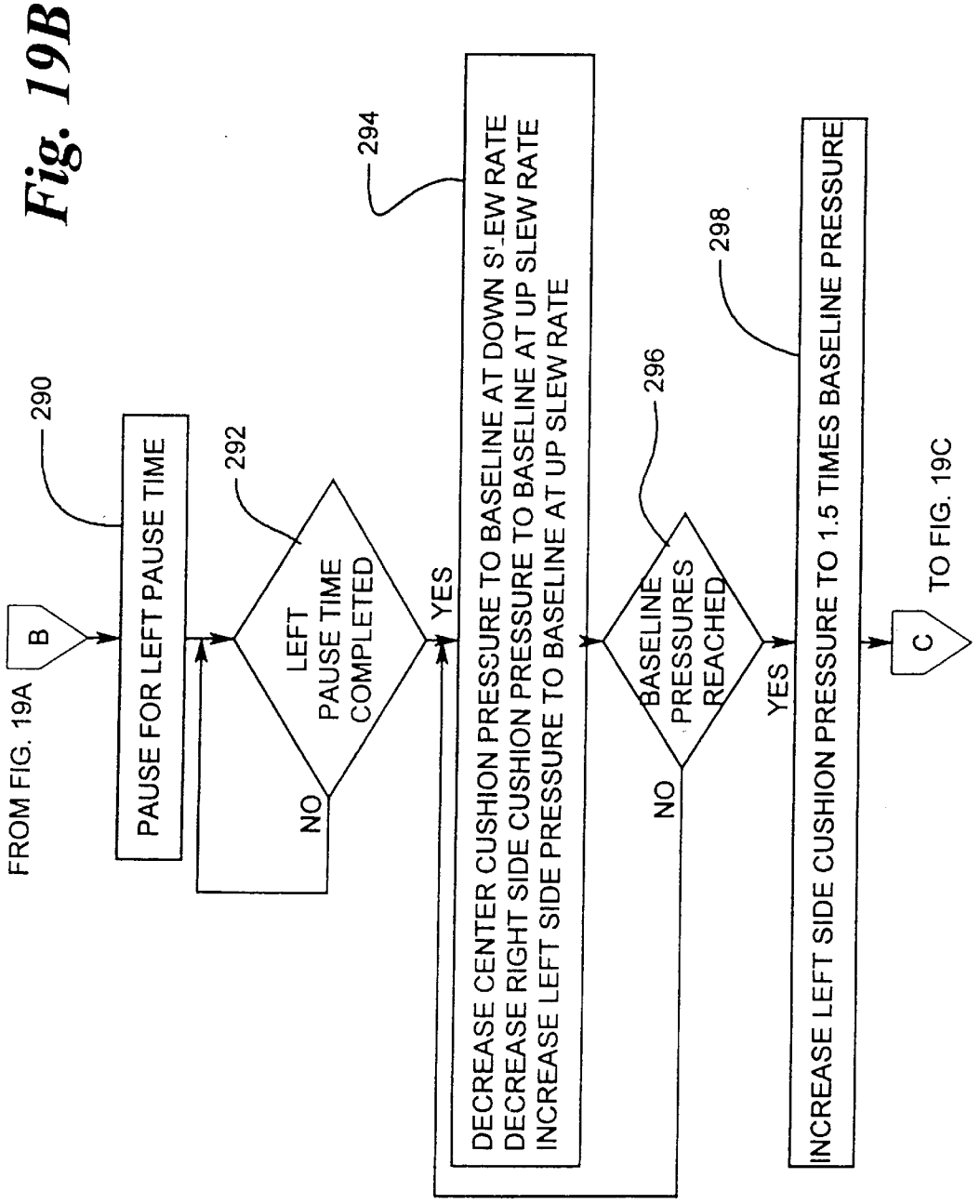

FROM FIG. 19A
B
290
PAUSE FOR LEFT PAUSE TIME
292
LEFT PAUSE TIME COMPLETED
NO
YES
294
DECREASE CENTER CUSHION PRESSURE TO BASELINE AT DOWN SLEW RATE
DECREASE RIGHT SIDE CUSHION PRESSURE TO BASELINE AT UP SLEW RATE
INCREASE LEFT SIDE PRESSURE TO BASELINE AT UP SLEW RATE
296
BASELINE PRESSURES REACHED
NO
YES
298
INCREASE LEFT SIDE CUSHION PRESSURE TO 1.5 TIMES BASELINE PRESSURE
C
TO FIG. 19C

Fig. 19C

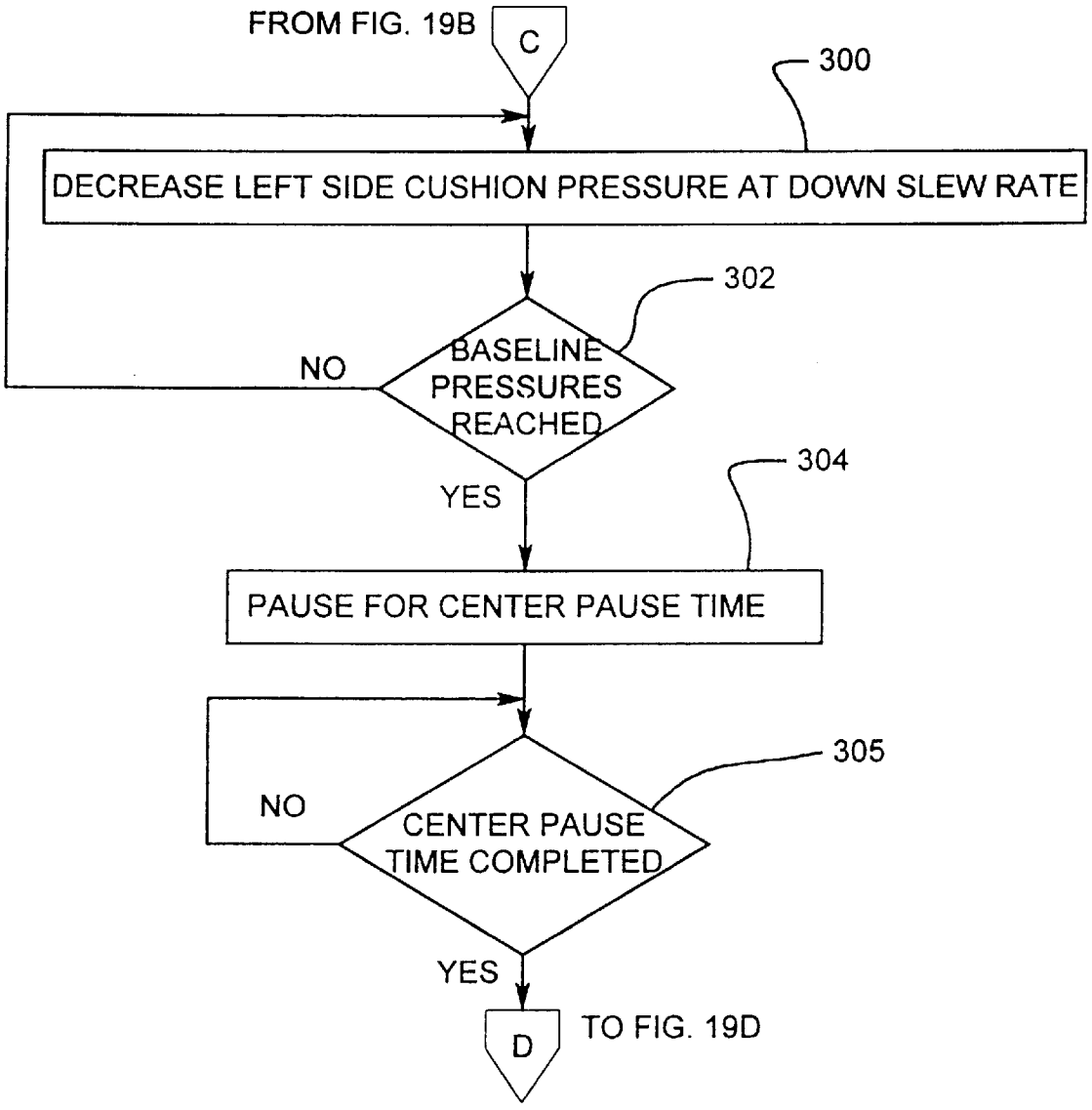

FROM FIG. 19B
C
300
DECREASE LEFT SIDE CUSHION PRESSURE AT DOWN SLEW RATE
302
BASELINE PRESSURES REACHED
NO
YES
304
PAUSE FOR CENTER PAUSE TIME
305
CENTER PAUSE TIME COMPLETED
NO
YES
D
TO FIG. 19D

Fig. 19D

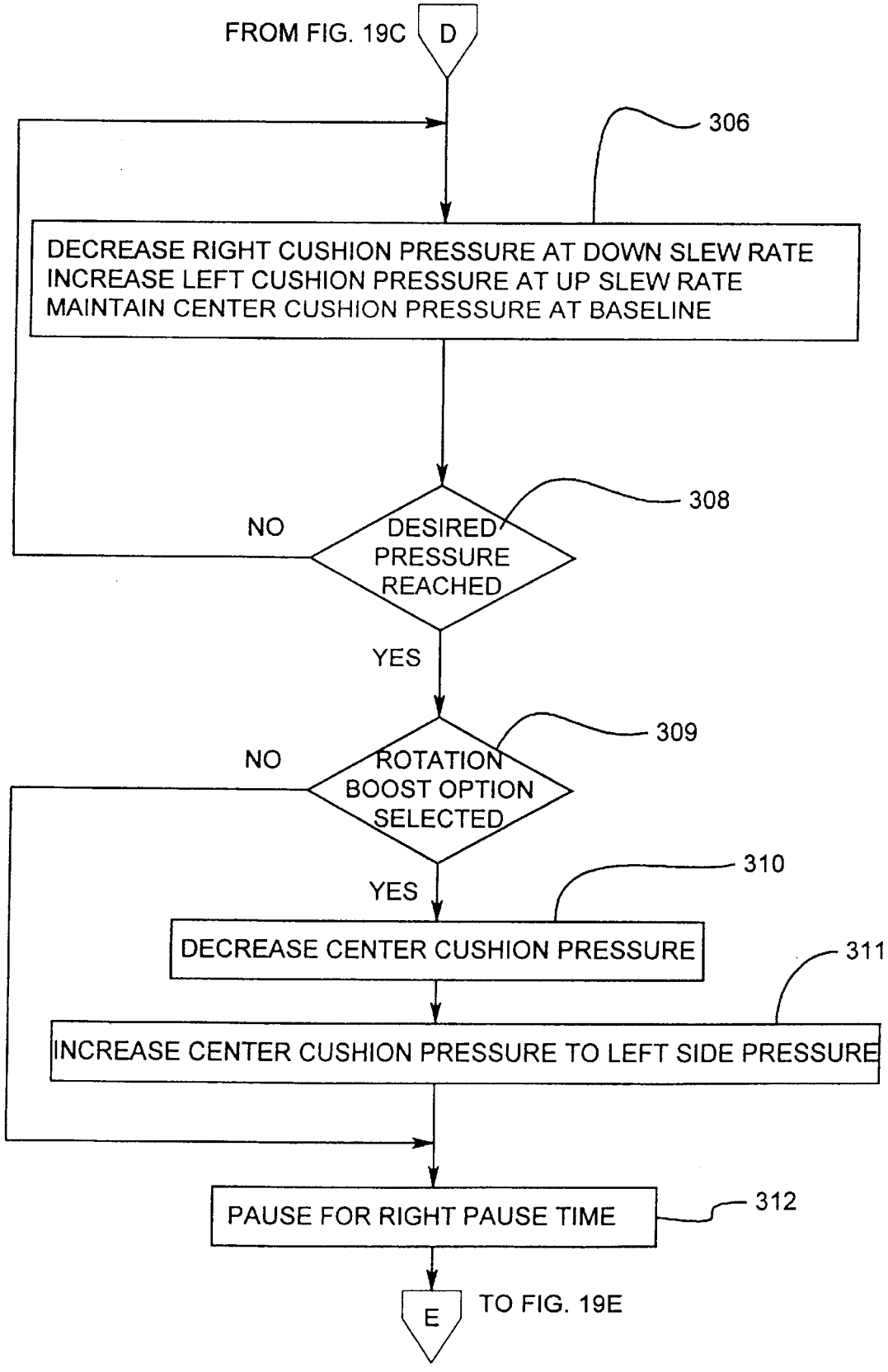

FROM FIG. 19C
D
306
DECREASE RIGHT CUSHION PRESSURE AT DOWN SLEW RATE
INCREASE LEFT CUSHION PRESSURE AT UP SLEW RATE
MAINTAIN CENTER CUSHION PRESSURE AT BASELINE
308
NO
DESIRED PRESSURE REACHED
YES
309
NO
ROTATION BOOST OPTION SELECTED
YES
310
DECREASE CENTER CUSHION PRESSURE
311
INCREASE CENTER CUSHION PRESSURE TO LEFT SIDE PRESSURE
PAUSE FOR RIGHT PAUSE TIME
312
E
TO FIG. 19E

Fig. 19E

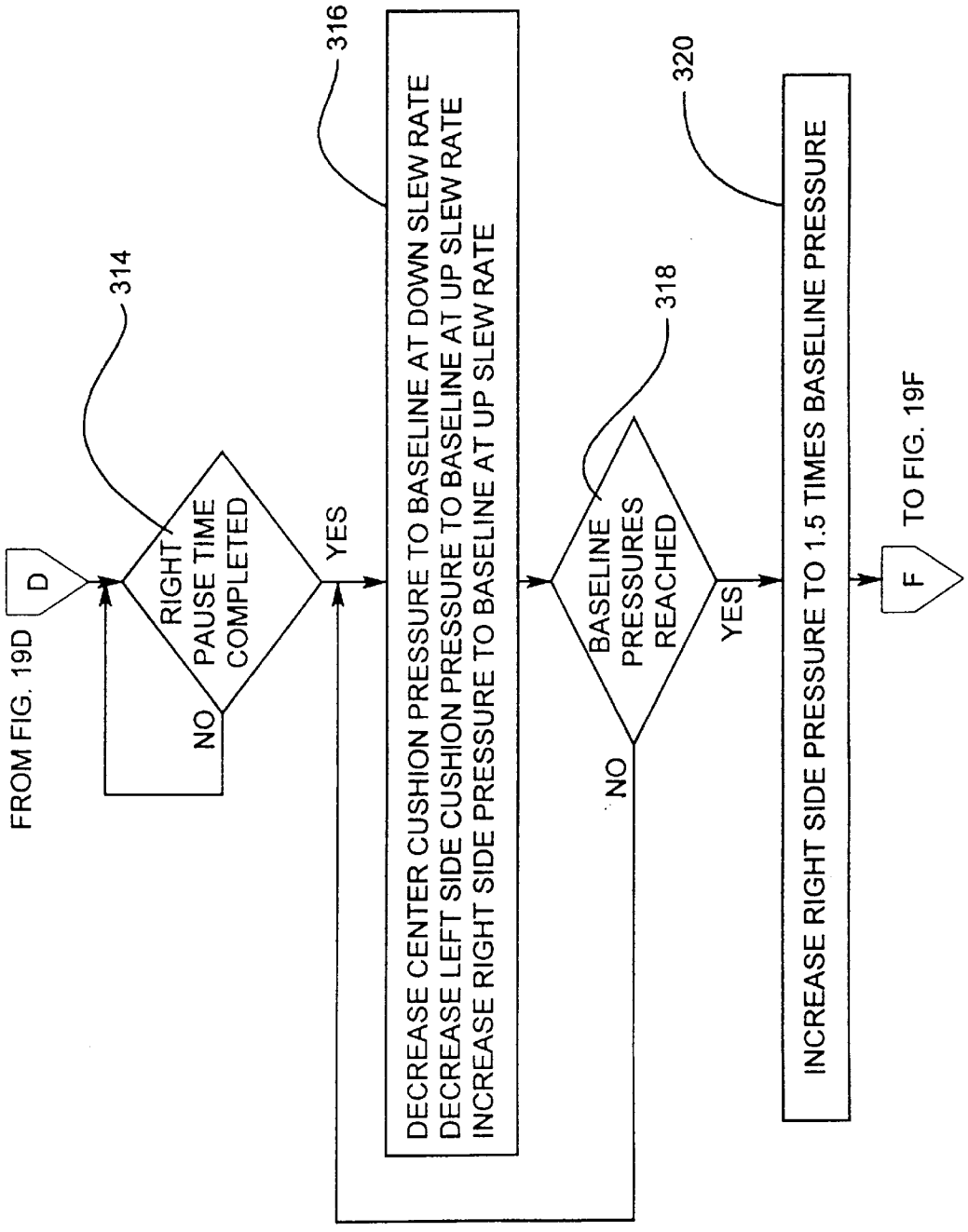

FROM FIG. 19D
D
314
RIGHT PAUSE TIME COMPLETED
NO
YES
316
DECREASE CENTER CUSHION PRESSURE TO BASELINE AT DOWN SLEW RATE
DECREASE LEFT SIDE CUSHION PRESSURE TO BASELINE AT UP SLEW RATE
INCREASE RIGHT SIDE PRESSURE TO BASELINE AT UP SLEW RATE
318
BASELINE PRESSURES REACHED
NO
YES
320
INCREASE RIGHT SIDE PRESSURE TO 1.5 TIMES BASELINE PRESSURE
F
TO FIG. 19F

Fig. 19F

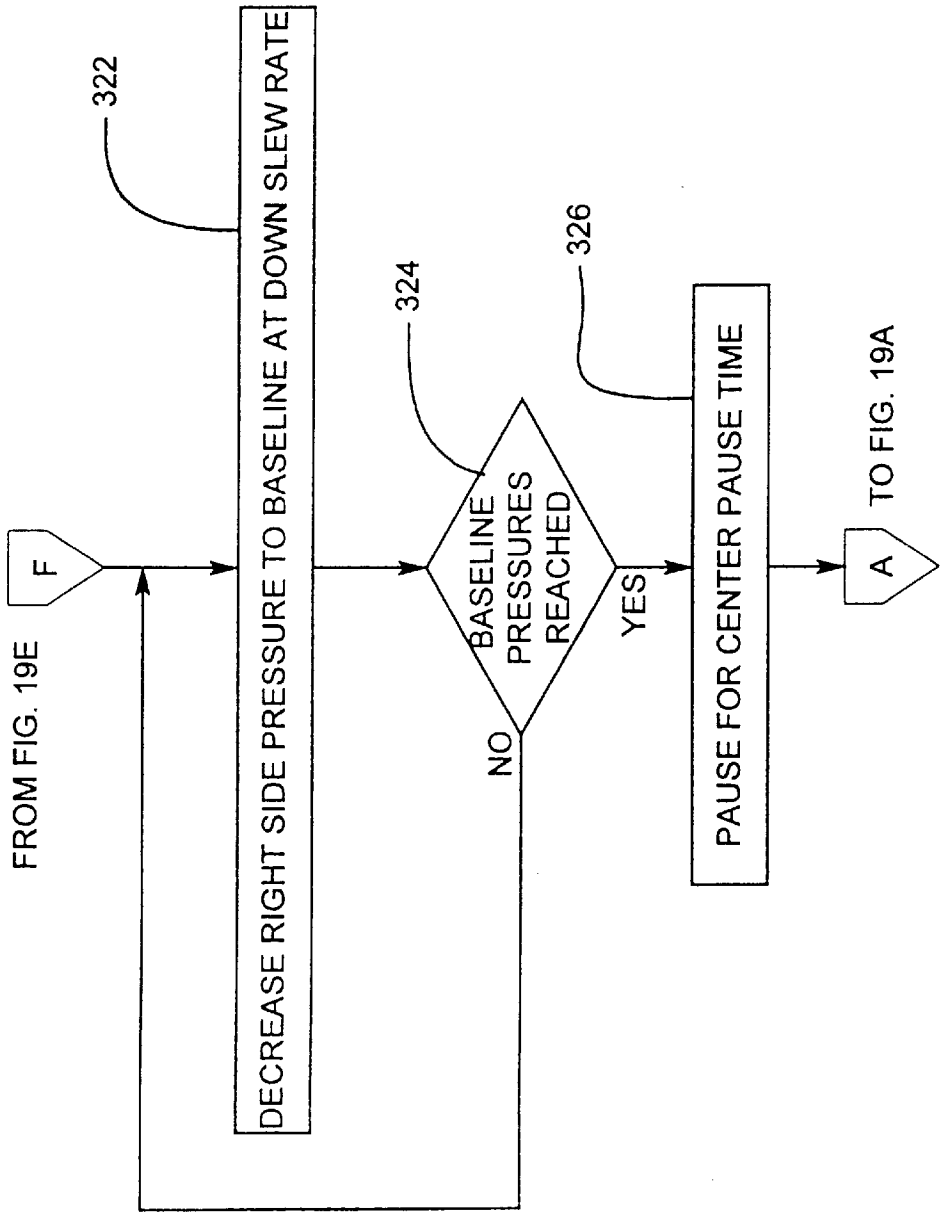

FROM FIG. 19E
F
322
DECREASE RIGHT SIDE PRESSURE TO BASELINE AT DOWN SLEW RATE
324
BASELINE PRESSURES REACHED
NO
YES
326
PAUSE FOR CENTER PAUSE TIME
A
TO FIG. 19A

Fig. 20

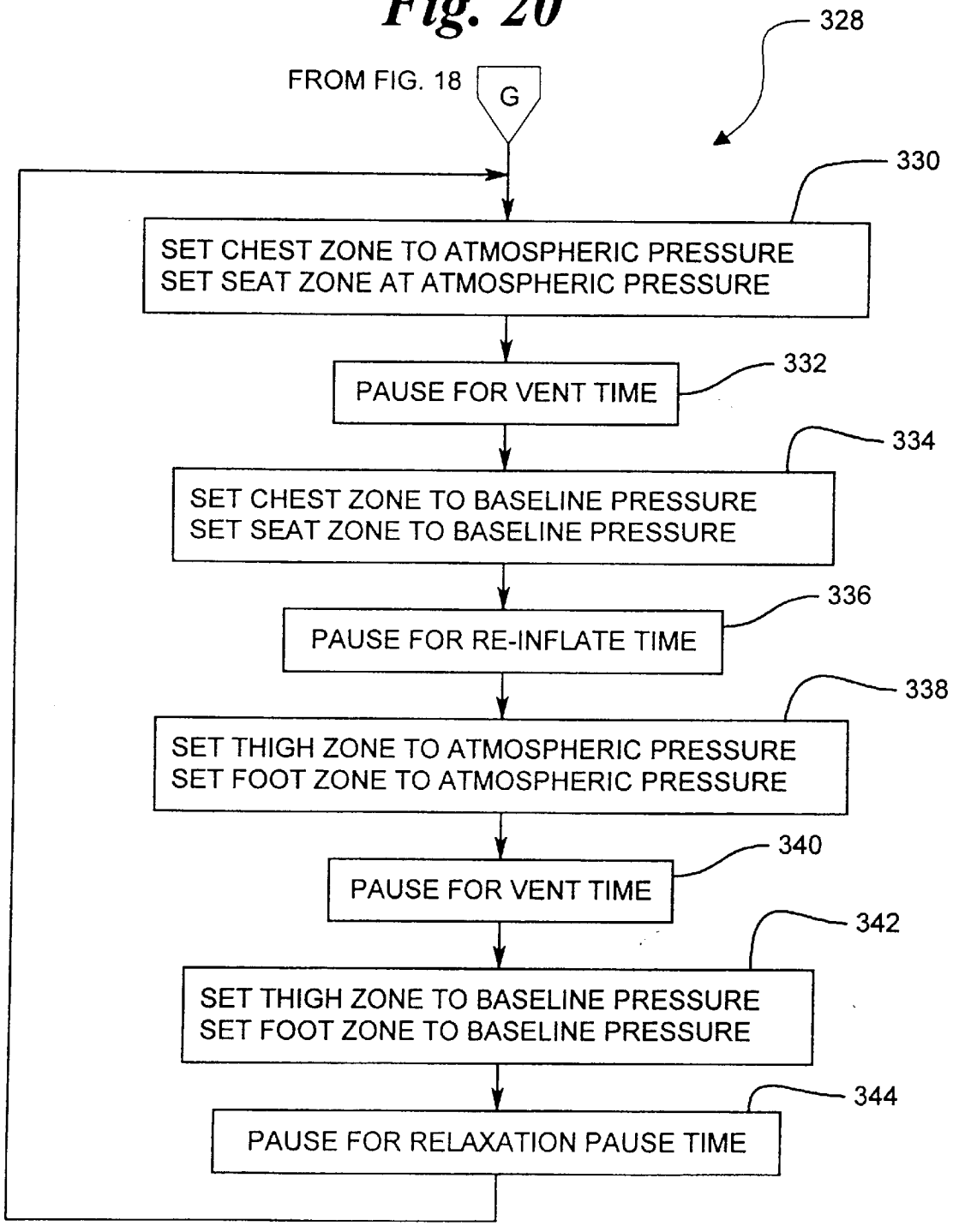

328
FROM FIG. 18
G
330
SET CHEST ZONE TO ATMOSPHERIC PRESSURE
SET SEAT ZONE AT ATMOSPHERIC PRESSURE
PAUSE FOR VENT TIME
332
334
SET CHEST ZONE TO BASELINE PRESSURE
SET SEAT ZONE TO BASELINE PRESSURE
PAUSE FOR RE-INFLATE TIME
336
338
SET THIGH ZONE TO ATMOSPHERIC PRESSURE
SET FOOT ZONE TO ATMOSPHERIC PRESSURE
PAUSE FOR VENT TIME
340
342
SET THIGH ZONE TO BASELINE PRESSURE
SET FOOT ZONE TO BASELINE PRESSURE
PAUSE FOR RELAXATION PAUSE TIME
344

Fig. 21

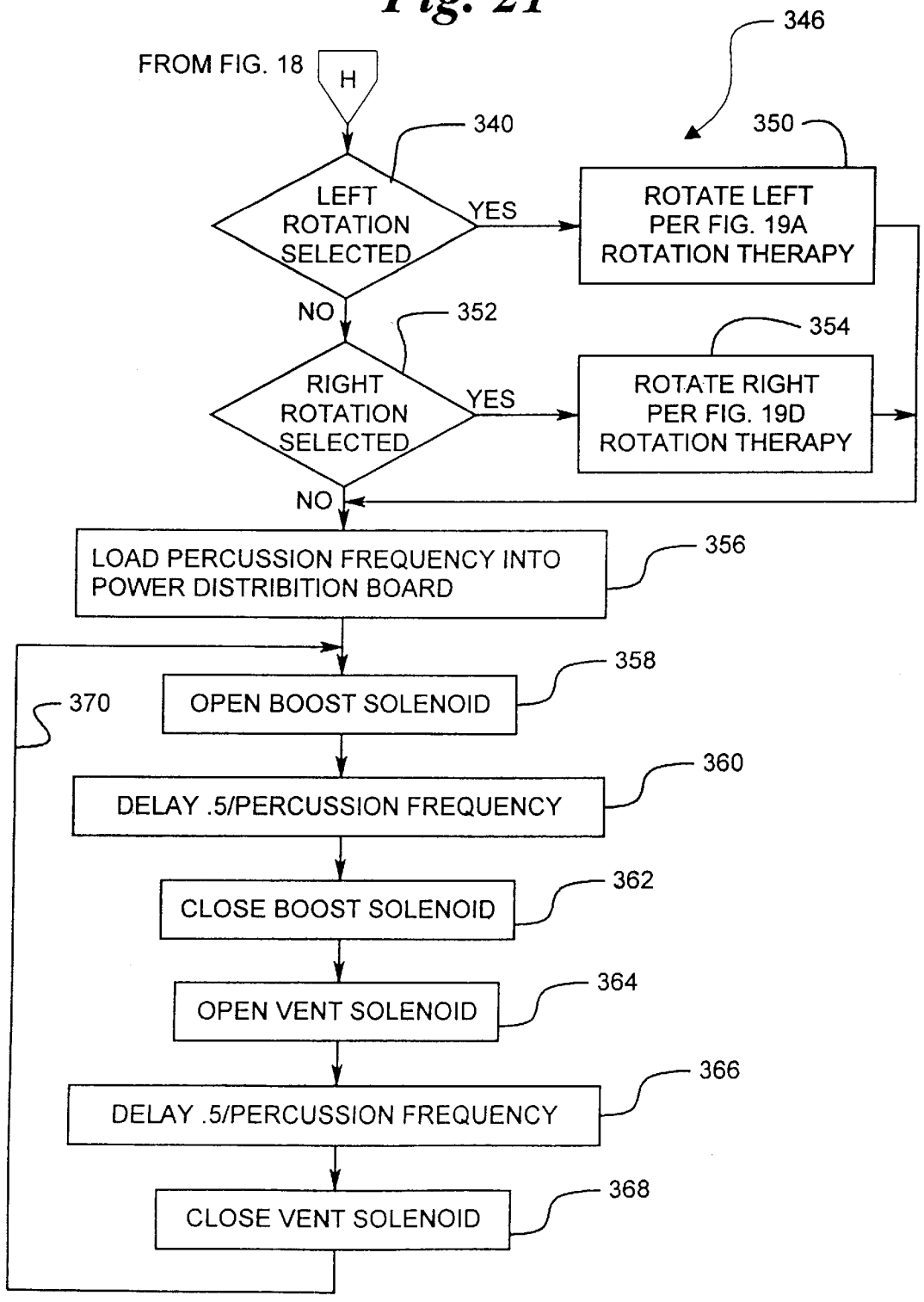

FROM FIG. 18
H
340
LEFT ROTATION SELECTED
YES
346
350
ROTATE LEFT PER FIG. 19A ROTATION THERAPY
NO
352
RIGHT ROTATION SELECTED
YES
354
ROTATE RIGHT PER FIG. 19D ROTATION THERAPY
NO
LOAD PERCUSSION FREQUENCY INTO POWER DISTRIBITION BOARD
356
370
OPEN BOOST SOLENOID
358
DELAY .5/PERCUSSION FREQUENCY
360
CLOSE BOOST SOLENOID
362
OPEN VENT SOLENOID
364
DELAY .5/PERCUSSION FREQUENCY
366
CLOSE VENT SOLENOID
368

Fig. 22

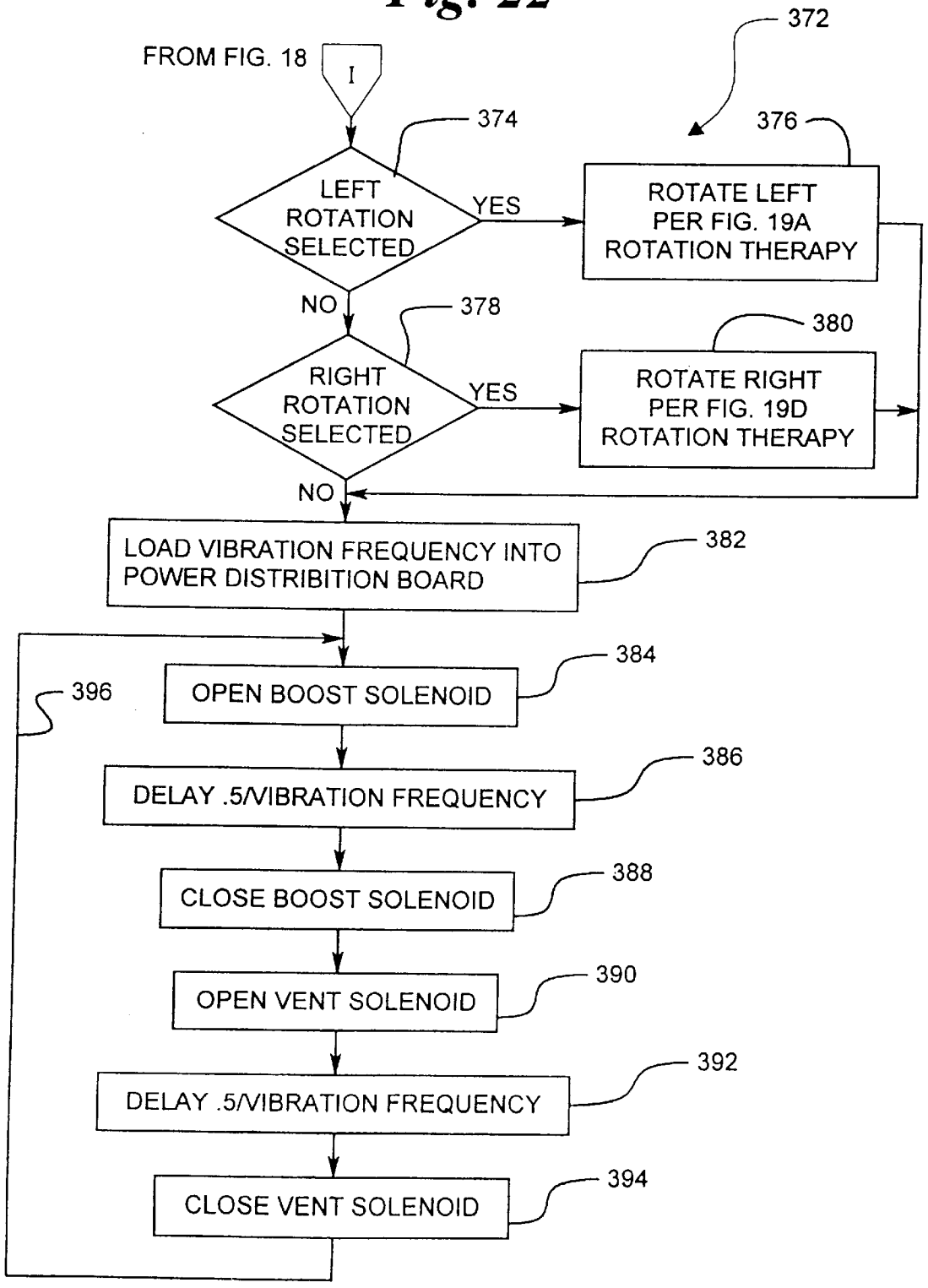

FROM FIG. 18
I
372
374
376
LEFT ROTATION SELECTED
YES
ROTATE LEFT PER FIG. 19A ROTATION THERAPY
NO
378
380
RIGHT ROTATION SELECTED
YES
ROTATE RIGHT PER FIG. 19D ROTATION THERAPY
NO
LOAD VIBRATION FREQUENCY INTO POWER DISTRIBITION BOARD
382
384
396
OPEN BOOST SOLENOID
386
DELAY .5/VIBRATION FREQUENCY
388
CLOSE BOOST SOLENOID
390
OPEN VENT SOLENOID
392
DELAY .5/VIBRATION FREQUENCY
394
CLOSE VENT SOLENOID

Fig. 23

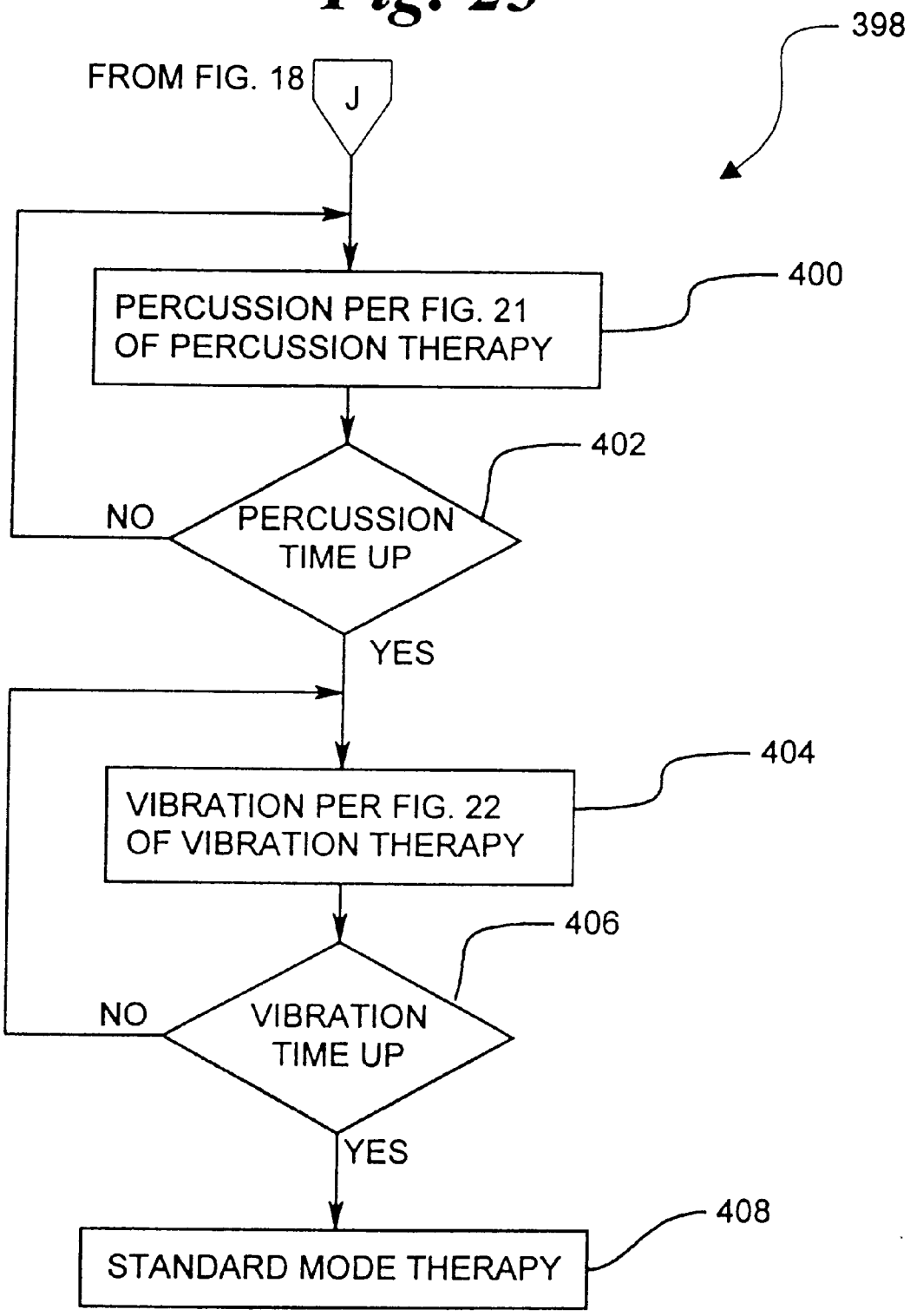

398
FROM FIG. 18
J
PERCUSSION PER FIG. 21
OF PERCUSSION THERAPY
400
402
NO
PERCUSSION
TIME UP
YES
VIBRATION PER FIG. 22
OF VIBRATION THERAPY
404
406
NO
VIBRATION
TIME UP
YES
STANDARD MODE THERAPY
408

Fig. 25

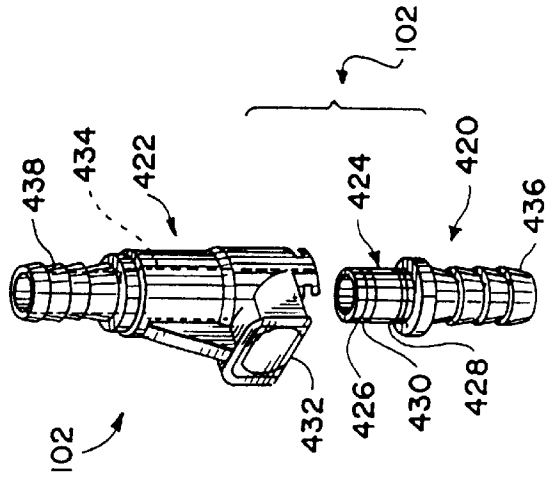
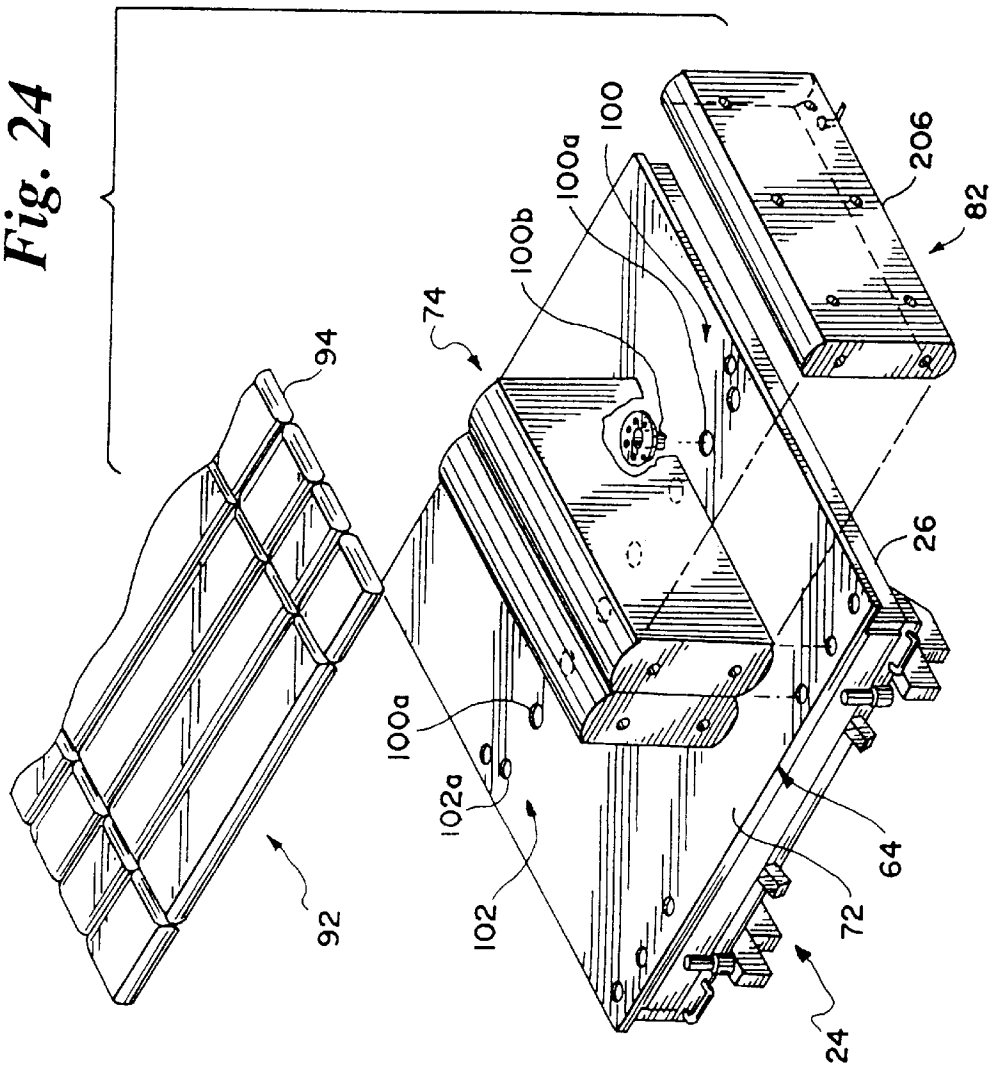

102
438
434
422
424
420
436
432
426
430
428
102

Fig. 24


100
100a
100b
206
82
74
94
26
100a
102a
102
64
72
92
24

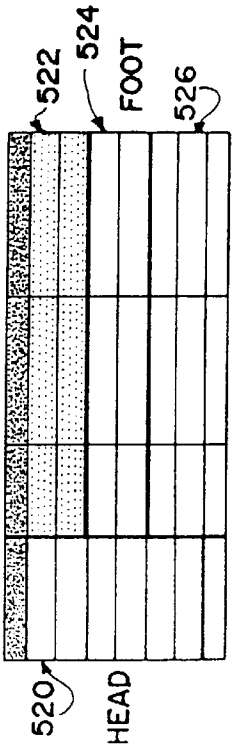


Fig. 27A

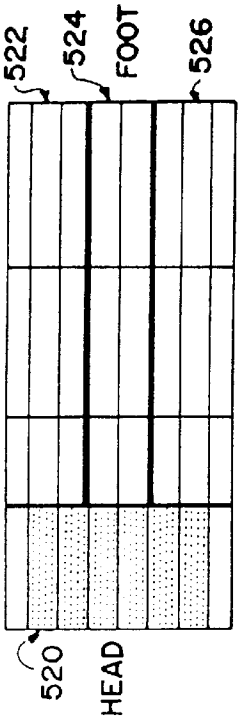


Fig. 27B

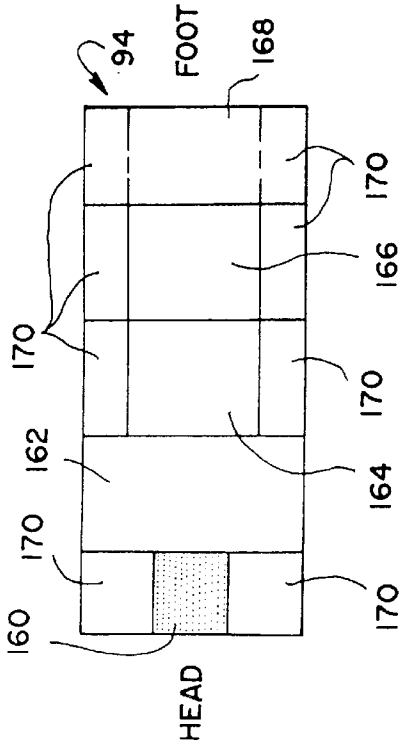


Fig. 26A

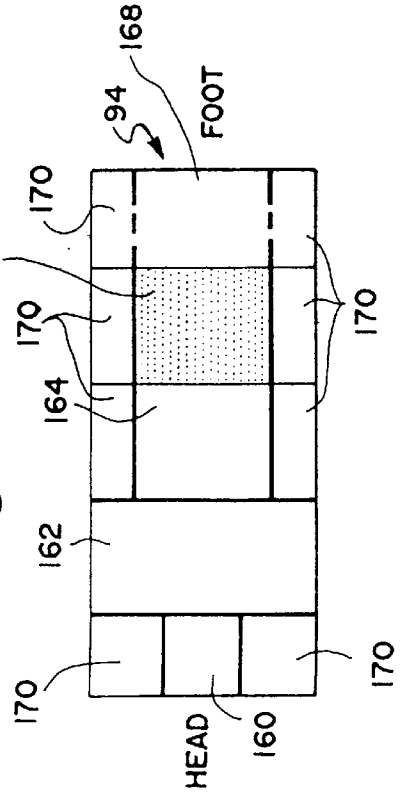


Fig. 26B

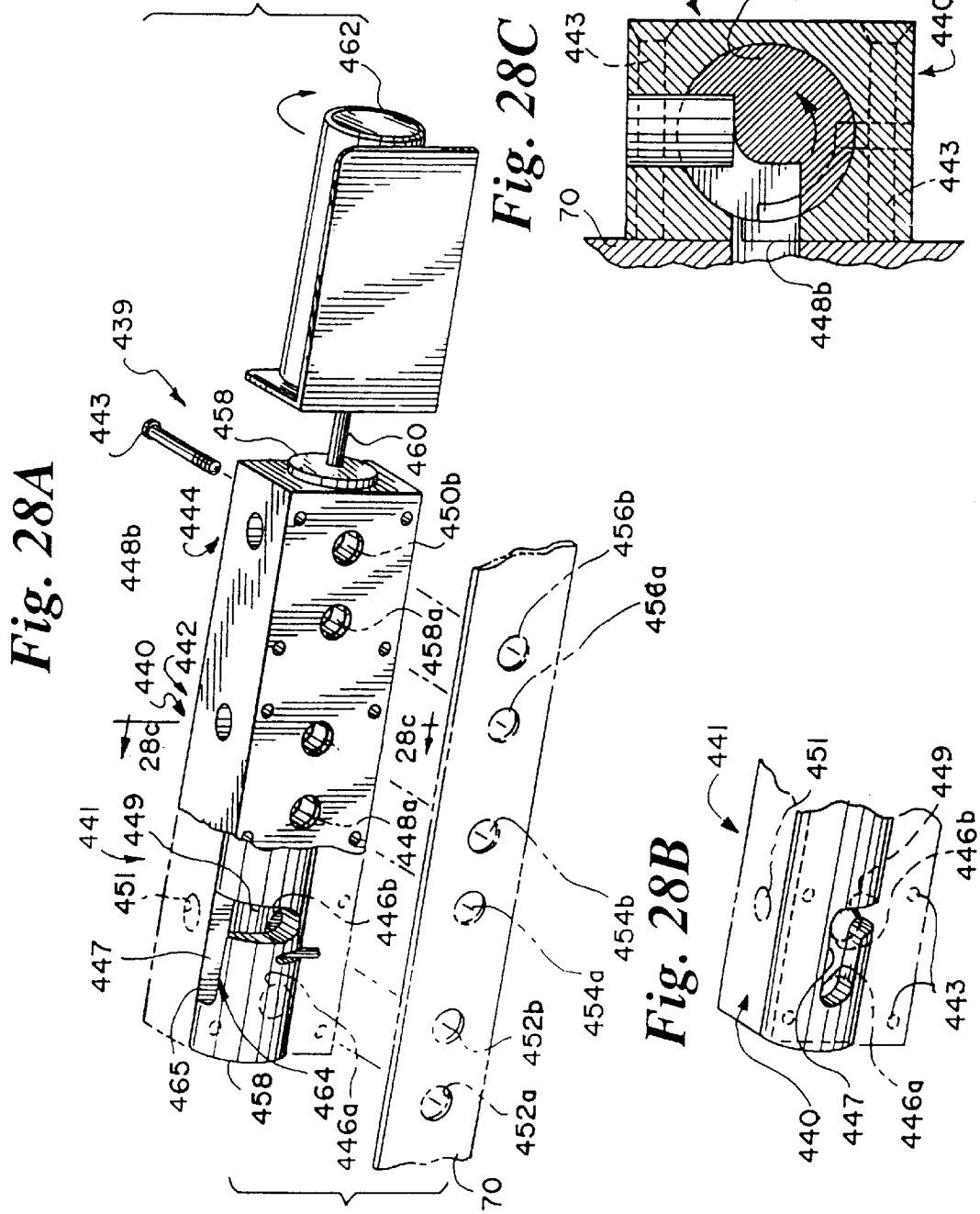


Fig. 28A
462
439
443
458
460
444
448b
450b
456b
456a
458a
440
442
28c
441
449
451
448a
446b
447
454b
454a
452b
452a
465
458
464
446a
70
Fig. 28C
442
458
440
443
70
443
448b
Fig. 28B
441
451
449
446b
443
440
447
446a

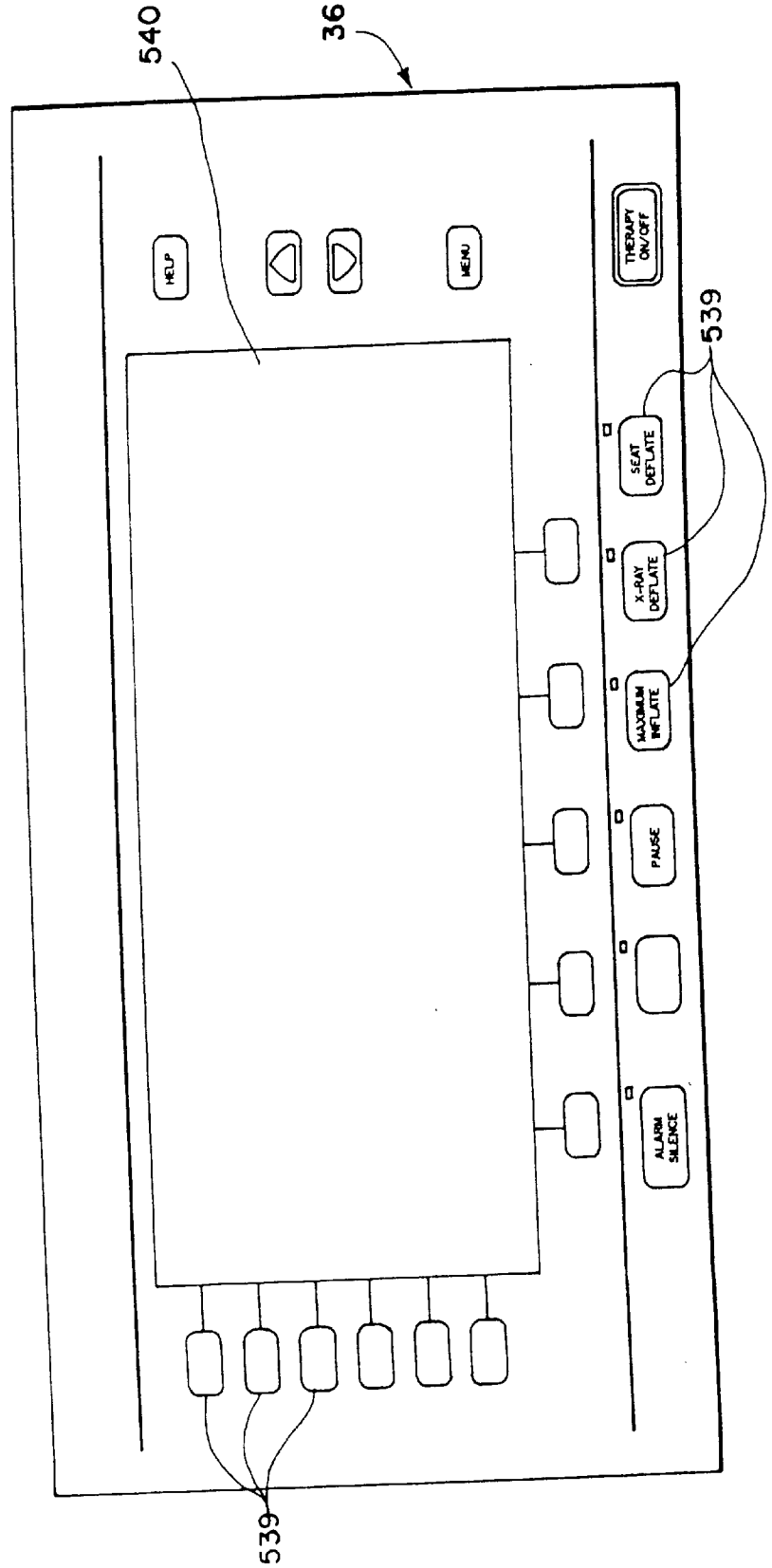

540
36
HELP
MENU
THERAPY ON/OFF
539
SEAT DEFLATE
X-RAY DEFLATE
MAXIMUM INFLATE
PAUSE
ALARM SILENCE
539

Fig. 29

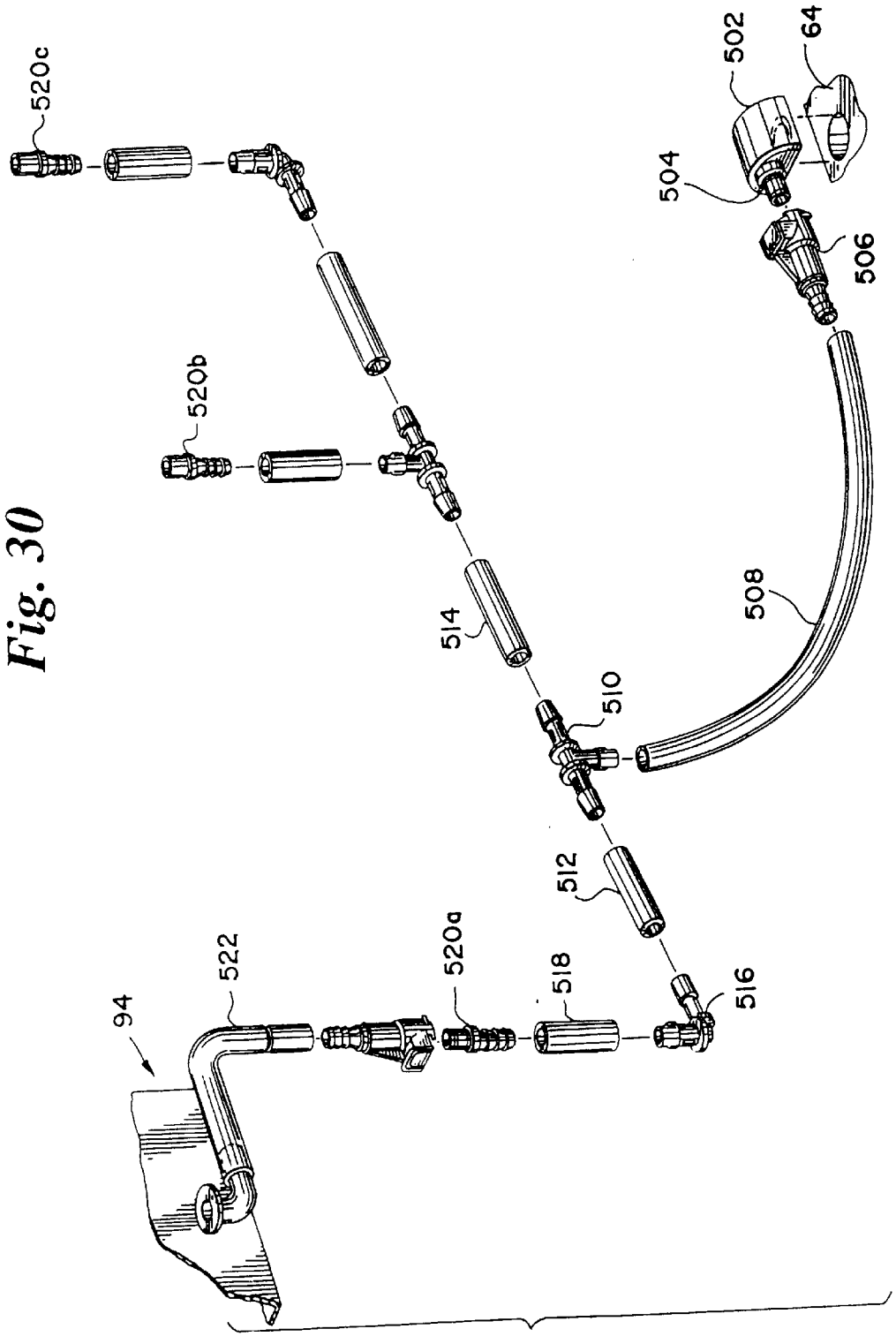


Fig. 30

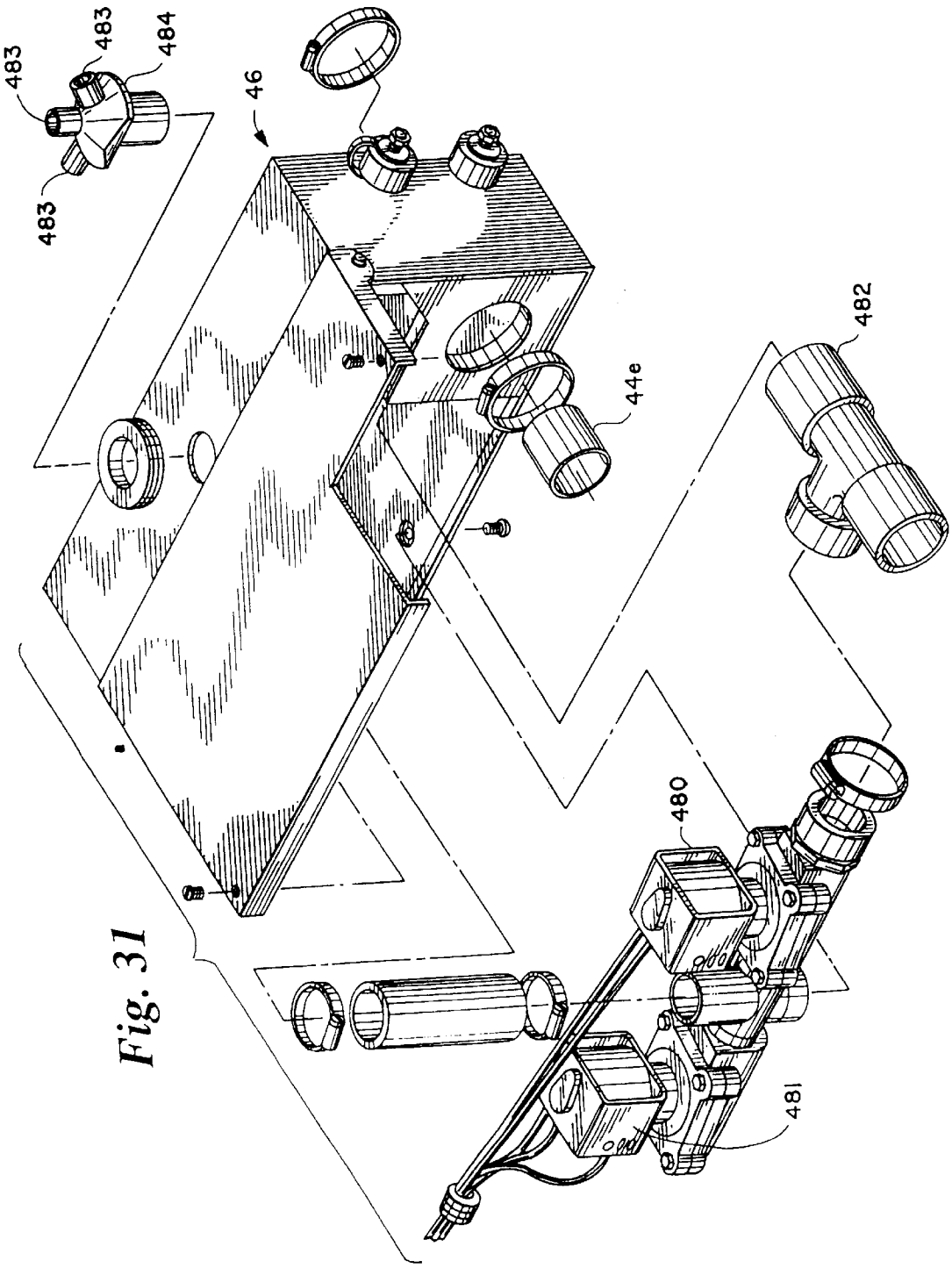


Fig. 31

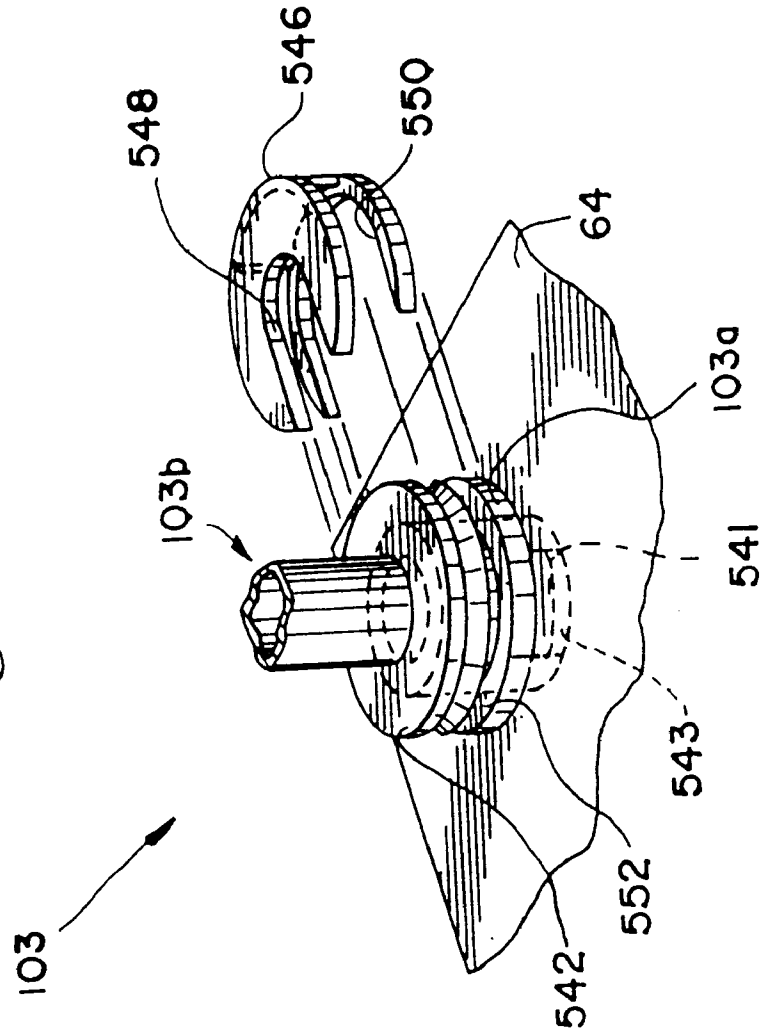


Fig. 32

METHOD AND APPARATUS FOR SUPPORTING AND FOR SUPPLYING THERAPY TO A PATIENT

This is a continuation of application Ser. No. 08/780,050 filed Dec. 23, 1996, which is a continuation of Ser. No. 08/196,047 filed Feb. 15, 1994, now U.S. Pat. No. 5,586,346.

BACKGROUND OF THE INVENTION

The present invention relates generally to inflatable support surface beds, and more specifically relates to inflatable support surface beds providing low air loss patient support, or providing other therapies, to a patient supported thereon.

Numerous types of inflatable patient support surfaces have been proposed to support patients. One generic configuration of such a support system in use today includes a plurality of transverse air bags extending across the width of the bed support surface. A plurality of such bags are arranged in parallel to form either a part, or the entirety, of the patient support surface. As is well known relative to such beds, a blower supplies air through a manifolding system to each of the air bags. This manifolding system includes a controller, such as a microprocessor controller, which operates a plurality of valves to control the air flow to sets of one or more of the air bags forming "zones" of the bed.

One therapy offered by such beds is low air loss patient support. In this configuration, at least some of the bags will include either small apertures, or will be formed in whole or in part of air permeable fabric, to provide a flow of air to dry the bag and/or cover surface to thereby reduce the risk to the patient of bed sores.

Another therapy offered in conventional beds is turning, or lateral rotation, of the patient. Dramatically different systems exist in the prior art for turning a patient with transverse air bags. For example, one conventional system deflates alternate single-celled air bags along the length of the patient to allow the patient to drop into recesses or cutouts in the other set of air bags, which remain fully inflated. Another, different, system utilize the deflation of cells in multi-celled cushions all along the length of one side of the patient to lower that side of the patient, and the corresponding inflation of cells all along the length of the other side of the patient to simultaneously raise that side of the patient. The different approaches of each of the systems may present disadvantages in certain situations, however. Both systems can offer less than optimal patient support over a long term in some applications.

Other therapies which are found in conventional acute care beds include pulsation and percussion. Pulsation, or alternating of contact (support) points, has long been utilized in an attempt to reduce patient tissue damage, such as decubitus ulcers. Examples of such alternating pressure surfaces include U.S. Pat. No. 2,998,817 to Armstrong, issued Sep. 5, 1961; and EPO Application No. 0-168-215 to Evans, published Jan. 15, 1986. Percussion therapy consists of a sharp impact of pressure, preferably only in the chest area of the patient, to assist in maintaining portions of the patients' body, typically the lungs, clear of pooled fluid. Conventional apparatus utilize a quick inflation of a cell beneath the patient to provide the impact. The frequency of the percussive therapy may be increased to provide vibratory therapy.

Notwithstanding what therapies are offered, a primary concern with an inflatable bed or support surface is patient comfort. Because patients may remain on these types of beds for extended periods of time, the ability to provide an optimally comfortable support surface is an important objective of any inflatable support assembly. This objective remains even when therapies such as those discussed above are offered.

Another objective of an inflatable support assembly will be to provide a system to maintain a patient properly positioned on the bed during normal situations. This may be of particular importance during rotational therapy. The prior art has only achieved this objective with a limited degree of success.

Accordingly, the present invention provides a new method and apparatus for supporting the patient on an inflatable support surface, and for providing optimal comfort and patient positioning, while having the further capacity, as desired, to provide a range of therapies such as, for example, low air loss support, rotation, varying support pressure ("relaxation"), percussion or vibration to the patient.

SUMMARY OF THE INVENTION

The present invention provides a bed having an improved support surface assembly, and provides a bed suitable for providing a variety of therapies to a patient through the improved support surface assembly. The support surface in accordance with the present invention preferably includes at least two independently inflatable layers. In one preferred embodiment of the support surface assembly, a lower layer of the support surface assembly includes first and second longitudinal cushion sets coupled to a support assembly, such as a support plate. The first longitudinal cushion set includes a plurality of generally parallel cells; which, in a particularly preferred embodiment, are formed as separate and distinct cushions. This first set of longitudinal cushions extends a portion of the longitudinal length of the support assembly; i.e., a portion of the longitudinal length or height of the patient. The second longitudinal cushion set is constructed similarly to the first longitudinal cushion set, but extends at a longitudinally offset portion of the length of the support assembly (or of the patient's length). One particularly preferred embodiment of the invention includes three such longitudinal cushion sets, sequentially longitudinally disposed beneath the patient. These longitudinal cushion sets provide control over the patient's positioning in the bed, and are independently inflatable in preferably at least three longitudinally—divided (i.e., laterally offset) groups, to facilitate rotation of the patient to the left and right through selective inflation and deflation of the longitudinally—divided groups.

In this preferred embodiment, disposed between the longitudinal cushion sets and the patient is an inflatable support layer. Preferably, this inflatable support layer is a discrete and separate assembly from the cells forming the lower layer of the support surface assembly. This inflatable support layer is preferably constructed to provide air leakage, or to otherwise facilitate the flow of air through the layer in at least selected locations. Further, this inflatable support layer preferably includes a predetermined number of independently controllable zones distributed around the patient's body whereby the pressure in individual zones can be adjusted to provide optimal patient comfort. Further, in a particularly preferred embodiment, one or more sections of the inflatable layer also include inflatable, relatively laterally external, enclosures which are maintained at a relatively increased pressure relative to a central enclosure to facilitate the cradling of the patient proximate the central portion of the bed. In addition to stabilizing the patient's position, these

cradling sections, at a higher pressure, also serve to stabilize the patient during rotation. Again in one particularly embodiment, the inflatable support layer also includes provisions under a selected portion of the patient's body, for example the chest area, for providing percussive or vibratory therapy to the patient to facilitate the loosening and movement of fluids from the patient's lungs.

An exemplary bed including a support surface as described above is preferably controlled through use of a conventional microprocessor system to regulate a plurality of proportional valves which modulate airflow between a blower assembly and the air cushions. Appropriate pressure feedback mechanisms and circuitry are provided to facilitate the microprocessor's monitoring of the pressure in the inflatable air cells relative to predetermined or desired levels, and appropriate regulation of the airflow to the cells.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts an exemplary bed constructed in accordance with the present invention.

FIG. **2** depicts a support frame assembly of the bed of FIG. **1**, depicted in an exploded view.

FIG. **3** depicts the support surface assembly of the bed of FIG. **1**, also depicted in an exploded view.

FIG. **4** is a schematic representation of the interconnection of air inlets and outlets in the support plate assembly of the bed of FIG. **1**.

FIG. **5** schematically depicts the vertical construction of the support plate of FIG. **4**.

FIG. **6** represents an exemplary illustration of the construction of the support plate assembly of FIG. **4**, illustrated in vertical section.

FIG. **7** schematically depicts the air manifold and a valve box of the support frame assembly of FIG. **2**.

FIGS. **8**A–D depicts a head section working cushion of the support surface assembly of FIG. **3**, illustrated with internal structure depicted in phantom lines; depicted in FIG. **8**A from a top view; depicted in FIG. **8**B from a side view; depicted in FIG. **8**C from a bottom view; and depicted in FIG. **8**D from an end view.

FIGS. **9**A–D depicts a seat section working cushion of the support surface assembly of FIG. **3** illustrated with internal structure depicted in phantom lines; depicted in FIG. **9**A from a top view; depicted in FIG. **9**B from a side view; depicted in FIG. **9**C from a bottom view; depicted in FIG. **9**D from an end view.

FIGS. **10**A–C depicts a leg section working cushion of the support surface assembly of FIG. **3** illustrated with internal structure depicted in phantom lines; depicted in FIG. **10**A from a top view; depicted in FIG. **10**B from a side view; and depicted in FIG. **10**C from a bottom view.

FIG. **11** depicts the overlay assembly of the support surface assembly of FIG. **3**, illustrated from a top view.

FIGS. **12**A–D depict the head section of the overlay assembly of FIG. **11**, illustrated with internal structure depicted in phantom lines; depicted in FIG. **12**A from a top view; depicted in FIG. **12**B from a side view; depicted in FIG. **12**C from a bottom view; and depicted in FIG. **12**D from an end view.

FIGS. **13**A–C depict the chest section of the overlay assembly of FIG. **11**, depicted in FIG. **13**A from a top view and depicting internal cells; and depicted in FIGS. **13**B and C from opposing side views.

FIGS. **14**A–D depict a section of the overlay assembly of FIG. **11** as is used with the seat or thigh sections, illustrated with internal structure depicted in phantom lines; depicted in FIG. **14**A from a top view; depicted in FIG. **14**B from a side view; depicted in FIG. **14**C from a bottom view; and depicted in FIG. **14**D from an end view.

FIGS. **15**A–D depict a cushion as is used in combination to form the foot section of the overlay assembly of FIG. **11**; depicted with internal structure depicted in phantom lines; depicted in FIG. **15**A from a top view; depicted in FIG. **15**B from a side view; depicted in FIG. **15**C from a bottom view; and depicted in FIG. **15**D from an end view.

FIG. **16** schematically depicts an exemplary electrical control circuit useful with the bed of FIG. **1**.

FIG. **17** depicts an exemplary flowchart for the patient pressure baseline setup routine for a bed in accordance with the present invention.

FIG. **18** depicts an exemplary flowchart for the setup of blower pressure for a bed in accordance with the present invention.

FIGS. **19**A–F depict an exemplary flowchart for the implementation of rotation therapy in a bed in accordance with the present invention.

FIG. **20** depicts an exemplary flowchart for implementation of pressure relief, or "relaxation", therapy for a bed in accordance with the present invention.

FIG. **21** depicts an exemplary flowchart for implementation of percussion therapy for a bed in accordance with the present invention.

FIG. **22** depicts an exemplary flowchart for implementation of vibration therapy for a bed in accordance with the present invention.

FIG. **23** depicts an exemplary flowchart for implementation of combination percussion and vibration therapy for a bed in accordance with the present invention.

FIG. **24** depicts a portion of the insertion of working cushions on a portion of support frame assembly of support surface assembly of FIG. **3**.

FIG. **25** depicts an exemplary connector suitable for use in connecting tubing or other members to supply air between the support plate assembly and the overlay assembly of FIG. **11**.

FIGS. **26**A–B schematically depict the zones of the overlay assembly of FIG. **11**, illustrating the independently controllable portions thereof.

FIGS. **27**A–B schematically depict the zones of the working cushions of FIG. **3**, and the independently adjustable portions thereof.

FIGS. **28**A–C depict an exemplary seat dump valve useful with the present invention.

FIG. **29** depicts a front view of an exemplary control panel useful with the bed of FIG. **1**.

FIG. **30** depicts an exemplary assembly as may be used to supply air to cells in the overlay assembly of FIG. **11**, and in particular to the foot section thereof.

FIG. **31** depicts an exemplary embodiment of air box assembly of FIGS. **2** and **7**, depicted in an exploded view to show internal structure.

FIG. **32** depicts a clip-retained connector as may be utilized to establish fluid communication between the outermost cushions and the support surface of FIG. **3**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to the drawings in more detail, and particularly to FIG. **1**, therein is depicted an exemplary bed **20**

constructed in accordance with the present invention. Bed **20** includes a support frame assembly, indicated generally at **22**, and a support surface assembly, indicated generally at **24**.

Support frame assembly **22** preferably includes a conventional, multi-featured hospital bed frame **26**, such as the Century Critical Care Frame®, manufactured by Hill-Rom Co., a subsidiary of Hillenbrand Industries, of Batesville, Ind. Bed frame **26** includes conventional bed position functions and controls to change the bed height, articulation, etc.; and also includes conventional mechanisms, such as siderails **28** for patient safety. Coupled to bed frame **26** is a headboard assembly **32** and a footboard assembly **34**. Footboard assembly **34** preferably includes a control panel **36** which includes an LCD screen and a plurality of membrane switches. Control panel **36** controls air support and therapy functions of bed **20**, as will be described in more detail later herein.

Referring also to FIG. **2**, therein is depicted support frame assembly **22** in an exploded view. Support frame assembly **22** includes a blower and air filter assembly **40** operably coupled to frame **26**. Blower and air filter assembly **40** will be selected to provide an output based upon the desired pressure range desired for inflation of the cells in support surface assembly **24** and the determined leakage rates from such cells.

An electrical box **41** and battery assembly **42** are also provided on frame **26**. Battery assembly **42** will provide power for the operation of bed **22** during transfer or other interruptions of power. Although bed **20** is designed to operate from conventional AC power (which is converted to DC power), battery assembly **42** includes batteries which provide a supply of DC power to operate at least basic patient support functions during periods of AC power interruption. Battery assembly **42** is of a conventional design and is operably coupled to the electrical control system of bed **20** in a conventional manner.

Blower **40** is operably coupled through an appropriate conduit assembly **44***a*, **44***b*, **44***c*, **44***d*, and **44***e* to an air box **46**. Conduit assembly **44** is partially formed of rigid channel conduit elements **44***b* and **44***d*, and includes appropriate flexible elements: flexible conduit **44***a* coupled between blower **40** and channel conduit **44***b*; flexible conduit **44***c* coupled between channel conduit **44***b* and rising conduit **44***d*; and flexible conduit **44***e* coupled between rising conduit **44***d* and air box **46**.

Referring now also to FIGS. **7** and **31**, air box **46** is operably coupled to a valve manifold **48**. Each of a plurality of valves **50** (for clarity, only one valve is illustrated) engages an outlet **52***a–j* on valve manifold **48** to selectively supply air to specific air channels throughout support surface assembly **24**, as will be described in more detail later herein. A hose assembly **54** couples to each valve **50** to provide fluid communication between the valve outlet **52** and support surface assembly **24**.

Air box **46** includes a pair of solenoid valves **480**, **481** which are in at least selective fluid communication with air from blower **40** through conduit assembly **44**, such as through a T-coupling **482** to which conduit **44***e* is coupled. Solenoid valves **480**, **481** provide control of air to outlet **484** to facilitate percussion and vibration therapy, as will be described later herein. Outlet **484** is depicted as having three outlet ports **483** which will be coupled by appropriate tubing to inlet ports **440** (in FIG. **4**) on the bottom side of support plate assembly **64** in parallel. Alternatively, more or fewer ports may be provided to facilitate the flow of air through conduits to selected chambers in support surface assembly **24**. First air control valve **480** is preferably energized to a normally closed position to block the passage of air to outlet **484**. Selective rapid actuation opening valve **480**, while valve **481** is in a closed condition will provide a pulse of air to outlet **484** (and thereby to selected chambers, in support surface assembly **24**). Subsequent closing of valve **480** while opening valve **481** will allow air to be expelled from outlet **484** through valve **481**.

Briefly, as is well-known in the art, each valve **50** is a proportional valve which is individually controlled, through appropriate feedback and control circuitry, by a microprocessor-based controller. As a portion of the feedback control, each valve **50** has a pressure feedback tube **56** (*a–j*) operably coupled between the outlet side of an individual valve **50** and a pressure sensor on a power control circuit board assembly (not illustrated) associated with the valve **50**. Additionally, a pressure feedback tube **56***k* is utilized to monitor pressure in manifold **48**.

An exemplary structure and method of operation of air control valves is described generally in U.S. Pat. No. 5,251,349, issued Oct. 12, 1993 to Thomas et al.; the disclosure of which is hereby incorporated herein by reference for all purposes. It should be understood, however, that any of a number of conventionally known valve configurations may be utilized with the present invention. Alternatively, each air control valve may be as disclosed in U.S. patent application Ser. No. 08/088,541, entitled "Proportional Control Valve for Patient Support System," filed Jul. 7, 1993 in the names of Ryszard S. Ozarowski et al. and assigned to the owner of the present invention; the disclosure of which is hereby incorporated herein by reference for all purposes.

A plurality of air channel monitoring tubes **58** are also each cooperatively arranged, at a first end with a valve **50** outlet, and at a second end to an access plate **60**. Each monitoring tube **58** will be closed proximate access plate **60** by a conventional releasable sealing mechanism (not illustrated). Air channel monitoring tubes **58** allow the external monitoring and/or variation of pressures within individual air channels in support plate assembly **64**.

As is familiar to those skilled in the art, a plurality of shroud panel assemblies **63**, **64**, and **65** attach to bed frame **26** to protect components of support frame assembly **22** and to provide aesthetic appeal of the assembly.

Referring now primarily to FIGS. **3** and **24**, therein is depicted support surface assembly **24** in greater detail. Coupled to bed frame **26** (only a portion of which is depicted for clarity) is a support plate assembly, indicated generally at **64**. Support plate assembly **64** provides a solid surface upon which is supported a first, lower, inflatable level **74** and a second, upper, inflatable level **92**. As will be described in more detail later herein, lower inflatable layer **74** and upper inflatable layer **92** are preferably each divided into a plurality of zones, separately coupled to individual proportional air control valves **50**.

Support plate assembly **64** preferably includes a plurality of four individual sections, **66**, **68**, **70**, and **72**, operably coupled to bed frame **26** to extend generally the full length between headboard assembly **32** and footboard assembly **34** (see FIG. **1**). First support frame section **66** includes a central radiolucent panel **98**. As is known to the art, radiolucent panel **98** is preferably formed of a composite phenolic resin, such as is known by the trade name Recitin; and facilitates the taking of X-rays of a patient without removing the patient from the bed **20**. A flexible strip **74***a–c* is secured between adjacent sections **66**, **68**, **70**, and **72** of support plate

assembly **64** to cover spaces between the sections which may change in size as bed frame **26** is articulated, thereby tilting sections **66**, **68**, **70**, and **72** relative to one another.

Support plate assembly **64** includes a plurality of releasable air connector members which facilitate releasable connections between enclosures in lower inflatable layer **74** and upper inflatable level **92**. In a preferred implementation, a first, pull-release "quick disconnect" form of connector, indicated generally at **100**, is utilized to selectively engage complimentary connectors on the air cushions of lower inflatable level **74**; and a second manual-release form of connector, indicated generally at **102**, is utilized to selectively engage complimentary connectors and tubing coupled to upper inflatable level **96** to establish fluid communication therewith. Quick disconnect connector members **100***a* (schematically represented by large circles in FIG. **4**, and as exemplary identified at **504**, **506**, and **508** in FIG. **4**), are configured to engage complimentary connector members **100***b* on the cushions of lower inflatable level **74**, and are generally described in reference to FIGS. **2**, **3**, **5**, and **6** of U.S. Pat. No. 5,251,349 to Thomas, et al., previously incorporated by reference. Connector members as depicted in U.S. Pat. No. 5,251,349 include a flange which rests against the upper surface of the support plate and an extension which extends through the support plate and to which a threaded coupling is attached to secure the connector member to the support plate. As an alternative, and preferred, construction, the flange of the connector may include a plurality of apertures to facilitate the securing of the connector member to the support plate through screws rather than through the described threaded coupling. An exemplary manual release connector **102** (schematically represented by smaller circles in FIG. **4**, and as exemplary identified at **502**), as is utilized to couple the tubing extending to upper inflatable level **94**, is described herein in reference to FIG. **25**.

A limited number of clip-retained couplings **103** are utilized to establish fluid communication between support plate assembly **64** and the laterally outermost cushions of lower inflatable layer **74**. These couplings are represented by double concentric circles in FIG. **4**, and are depicted and discussed herein in relation to FIG. **32**.

Referring now also to FIGS. **4–6**, therein is depicted, in FIG. **4**, support plate assembly **64** in a schematic view, and from side views in FIGS. **5** and **6**. Support plate assembly **64** is preferably a multi-level composite assembly which defines a plurality of air passageways; and which acts, therefore, as a manifold for distributing air from proportional valves **50** to individual zones in lower inflatable layer **74** and upper inflatable layer **92**.

Support plate assembly **64** is preferably constructed of a plurality of PVC layers **160**, **162**, **164** adhesively coupled together as a central core, with a layer of aluminum plate **166**, **168** at the top and bottom, respectively; and with a layer of an external plastic coating **170** extending around the entire assembly. As can best be seen in FIG. **5**, support plate assembly **64** is constructed with an exterior recess **174** at the lower surface so that support plate assembly **64** will fit partially within the confines of bed frame **26**. To form exterior recess **174**, support frame assembly **64** preferably includes only two PVC layers **160**, **162**, proximate the exterior edge, and includes only the upper aluminum layer **166** proximate the exterior edge.

In one particularly preferred embodiment, each PVC layer **160**, **162**, **164** will be formed of a layer of expand ed PVC foam having a thickness of approximately ten millimeters (or 0.39 inch). As depicted in FIG. **6**, each PVC layer will have paths (indicated exemplary at **176**) formed therein to provide the desired flow channels, as schematically depicted in FIG. **4**. The PVC layers **160**, **162**, **164** are bonded together, and to aluminum plates **166**, **168**, with an adhesive, such as a methacrylate adhesive. Each aluminum plate is preferably approximately 0.067 inch thick. Plastic coating layer **170** may be of any suitable type, such as, for example an ABS/PVC blend, such as that marketed under the name Kydex T, by the Kleerdex Company of Aiken, S.C.

Referring primarily to FIG. **4**, each section **66**, **68**, **70**, and **72** of support plate assembly **64** is preferably constructed to define two or three levels of flow paths (see FIG. **6**), defining ten distinct flow channels; indicated generally at **110**, **112**, **114**, **116**, **118**, **120**, **122**, **124**, **126**, **128**. Each of the above flow channels is operatively coupled to an air inlet **110***a*, **112***a*, **114***a*, **116***a*, **118***a*, **120***a*, **122***a*, **124***a*, **126***a*, **128***a*, respectively on the lower side of section **66**. Each such air inlet is coupled through an appropriate conduit **52** to a respective air control valve **50**. Each flow channel **110**, **112**, **114**, **116**, **118**, **120**, **122**, **124**, **126**, **128** then extends through support plate assembly **64** to operatively couple to one or more quick disconnect connector members **100***a*, manual release connector member **102***a*, or clip-retained coupling **103** to provide fluid communication between a respective air control valve **50** and one or more cushions of first inflatable levels or zones of second inflatable level **96**. In many cases, an air channel **110**, **112**, **114**, **116**, **118**, **120**, **122**, **124**, **126**, **128** extends across one section **66**, **68**, **70**, or **72** of support frame assembly **64** to another such section. For example, air passageway **110** extends at **130** between first section **66** and second section **68** of support plate assembly **64**. In such cases, a conventional coupling will be secured to extend from the lower surface of each section, and a flexible tube or bellows (not illustrated) will be connected to the couplings to connect the air channel between such sections.

As can also be seen in FIG. **3**, bed **20** includes first, lower inflatable level, indicated generally at **74**, supported upon support plate assembly **64**. First inflatable level **74** is preferably formed of a plurality of generally longitudinally extending cells. In one preferred embodiment, these longitudinally extending cells are formed of individual longitudinally extending cushions, indicated generally at **76**, arranged generally in parallel in three longitudinally—extending, sequentially arranged, groups, **78**, **80** and **82**.

As can be seen in FIGS. **1** and **3**, each group **78**, **80**, **82** of longitudinal cushions **76** includes eight generally parallel, longitudinally extending cushions. First cushion group **78** will extend primarily under the head and upper torso of the patient. The cushions of first cushion group **78** are coupled together at an upper end by a first fabric panel **83**, which couples to the end of each individual cushion, preferably by a pair of conventional snap fittings. First fabric panel thereby serves to maintain the lateral spacing of the cushions of first cushion group **78** at the upper end. All snap fittings are preferably "Pull-The-Dot" snap fittings, such as Model Nos. 92-18100/92-18201, or 92-18302/93-10412 as manufactured by Scovill Fasteners, Inc. of Clarksville, Ga.

The second cushion group **80** will extend primarily under the seat and upper thigh portion of the patient. Each cushion of second cushion group **80** is coupled at an upper end to a respective cushion of first cushion group **78**. A transversely-extending fabric panel **84** extends between the cushions of first cushion group **78** and second cushion group **80** and includes apertures therein to facilitate the opening of the cushions through panel **84**. Similarly, the cushions of third cushion group **82**, which will extend generally under the legs

and feet of the patient, are again coupled together at an upper end, by snaps, to the cushions of second group **80** through apertures in a fabric panel **86**; and are coupled at the lower end to a fabric panel **90**. Each transverse fabric panel **83**, **84**, **86**, and **90** preferably includes at least one tab having a plurality of snap fittings therein to facilitate attachment to side panels **96**.

Each cushion **76** is preferably constructed of twill woven nylon coated on the interior surface with a sealing material, such as urethane, so as to make each cushion generally air tight. The cushions of each group will preferably be approximately 7.5 inches high, but will vary in length. In one preferred embodiment, the central six cushions of lower level **74** are each preferably approximately 4 inches wide, while the outermost "bolster" cushions are each approximately 2.5 inches wide. Other than as to material, the "working" cushions of each group **78**, **80**, and **82** will preferably be constructed somewhat differently from the cushions of other groups. Each working cushion may include at least one connector member which will engage a complimentary connector member on support surface assembly. In the depicted embodiment, the six most central cushions of each cushion group include a quick disconnect connector **100***b* by which the cushions are coupled to a complimentary connector **100***a* secured to support surface **64**. The two outermost cushions of each cushion group each include clip-retained fitting (**103***b* in FIG. **32**) by which fluid communication is established with receptacles **103***a* mounted on support surface **64**. Essentially identical side panels **96** will extend the longitudinal length of lower inflatable level **74**, and will preferably couple to each outer cushion and to each transverse panel **80**, **84**, **86**, **90** by a plurality of snaps. Each side panel **96** will then also couple, again by a plurality of snaps to an adjacent portion of support frame assembly **22**. Each side panel **96** also includes a closeable slot to facilitate the placement of an X-ray film magazine between the cushions of lower inflatable layer **74** and upper inflatable layer **92**, if so desired. Such slot may be closeable through use of a zipper, snaps, or a hook and eye fabric fastener.

Referring now to FIGS. **8**A–D, therein is depicted an exemplary head section cushion **180** of group **78**. In a particularly preferred embodiment, each head section cushion **180** is approximately 32 inches long. Each of the central six head section cushions **180** preferably includes two distinct, independently controllable chambers **182**, **184**. First chamber **182** is that portion which will lie under, and which will support, the patient's head. First chamber **182** includes a coupling **186** to cooperatively engage a length of tubing extending to a manual release connector **102** coupled to support surface assembly **64** (for example, items **502**, coupled to air channel **116** in FIG. **4**), by which chamber **182** may be supplied with air.

Second chamber **184** will lie under the upper torso or shoulders of the patient. Cushion **180** includes a connector **100***b* to provide fluid communication between chamber **184** and a complementary connector member **100***a* on support plate assembly **64**. (For example, items **504**, coupled to air channel **120**, for the center working cushion zone, in FIG. **4**.) Cushion **180** will also preferably include a pair of baffles, **190**, **192**, respectively, one in each chamber **182**, **184** to assist in maintaining the generally rectangular shape of cushion **180** during inflation. The outer two bolster head cushions will preferably each define only a single chamber.

Referring now to FIGS. **9**A–C, therein is depicted an exemplary seat working cushion **194** of group **80**. Seat section working cushion **194** is preferably approximately 22.8 inches long. Each of the central six seat section cushions **194** includes a single quick disconnect connector member **100***b* to facilitate attachment of cushion **194** to support plate assembly **64** (see item **506** for the center working cushion zone, coupled to air channel **120**, in FIG. **4**). Seat section cushion **194** is a generally rectangular cushion which defines a single internal chamber. A notch, or relief, **198**, however, is formed in lower surface **200** of cushion **194**. When seat section cushion **194** is installed on support plate assembly **64**, cushion **194** will extend across a central articulation point **202** of bed frame **26** (beneath flexible strip **74***b* in FIG. **3**). Articulation of support plate assembly **64** at articulation point **202** will cause adjacent surfaces of support plate assembly **64** to move relative to one another. Notch **198** will accommodate such motion in support plate assembly **64** without placing unacceptable stress on cushion **194**. Cushion **194** may also include one or more baffles **204** to facilitate the maintaining of the generally rectangular shape of cushion **204** during inflation.

Referring now to FIGS. **10**A–C, therein is depicted leg and foot cushion **206** of cushion **82**. Leg and foot cushion **206** will preferably again be approximately 22.8 inches in length. and foot cushion **206** is a generally rectangular cushion defining a single chamber, and (for the six central cushions) having a quick disconnect connector member **100***b* (which may couple, for example, to item **508**, for the center working cushion zone, and to air channel **120**, in FIG. **4**).

As will be apparent from the preceding discussion, considered in view of the schematic of FIG. **4**, the working cushions of first inflatable layer **74** are divided into four distinct zones. These zones are depicted, for example, in FIGS. **27**A–B, as head zone **520** (depicted in darkened fill-in FIG. **27**B) left zone **522** (depicted in darkened fill-in **27**A); center zone **524** and right zone **526**. Through control of appropriate valves as indicated in FIG. **4**, and thereby through control of air into air channels **110**, **116**, **120**, and **128**, the degree of inflation in each of these four zones may be regulated by control panel **36**.

Referring again to FIG. **3**, as previously discussed, bed **20** also includes a second, upper, inflatable level, indicated generally at **92**. Second inflatable level **92** is preferably a multi-celled overlay assembly **94** which extends essentially the full length of first (lower) inflatable level **74**. Lower and upper inflatable levels **74** and **92** will be held within a cover **95**. Cover **95** will preferably be formed of a moisture vapor permeable fabric, such as that marketed under the trade name Dermaflex by Consoltex Inc., of New York, N.Y.

Referring now to FIG. **11**, therein is depicted an exemplary embodiment of multi-section overlay assembly **94**, forming upper inflatable section **92**. Overlay assembly **94** may be constructed as a single unitary assembly. In a particularly preferred embodiment, however, overlay assembly **94** is formed of a plurality of, and most preferably of five, individual sections **148**, **150**, **152**, **154**, and **156**; with section **156** formed of three distinct cushions **157***a*, **157***b*, and **157***c*. Adjacent sections **148**, **150**, **152**, **154**, and each cushion **157***a–c* of section **156** are preferably coupled together along transverse beads **158***a*, **158***b*, **158***c*, and **158***d* to form the complete assembly. The coupling of individual sections together is preferably through releasable coupling systems, such as the previously described snap fittings.

Referring now also to FIGS. **26**A–B, overlay assembly **94** is utilized to provide primary control of patient comfort through control of interface pressures. Accordingly, overlay assembly **94** is preferably divided into six zones. A first,

"head", zone, indicated generally at **160** (depicted in darkened fill in FIG. **26**A), in first section **148** will support the patient's head.

A second "body" zone, indicated generally at **162**, supports the patient's upper torso. Second zone **162** preferably includes a plurality of cells which may be [individually] controlled to provide percussion and vibration therapy to the patient, as described later herein. Preferably, second zone **162** will include at least four cells, each of which will preferably extend generally transversely under the patient's upper torso.

Overlay assembly **94** then includes three additional relatively central zones, a "seat" zone **164**, a "thigh" zone **166**, and a "foot" zone **168**. An outer "bolster" or "cradle" zone **170** is intended to remain at relatively higher pressures than at least most of the above, relatively central, zones of overlay assembly **94**, and to thereby form a cradle for the patient. This bolster zone **170** may extend along both sides of each of the previously discussed zones. Preferably, the outer zone will extend on each side of all zones except second "upper torso" zone **162**, which will extend the full width of overlay assembly **92**. This cradle serves to maintain the patient in optimally central location on bed **20**. The cradle zone will also serve to maintain the patient generally centered during lateral rotation to thereby prevent the patient from slipping significantly to one side and to prevent the patient from contacting the bed siderails. In one preferred implementation the cradle zone will be maintained at a pressure approximately 2 inches of water higher than the pressure in seat zone **164**. During rotation, the cradle pressure may be increased, such as to approximately twice the pressure in the seat zone, or alternatively to approximately manifold pressure.

Overlay assembly **94** is preferably constructed in a low air loss configuration, wherein selected positions of the upper surface provide for the dispersal of air through the surface. Preferably, the seat and thigh sections **152** and **154** of overlay assembly **94** will be constructed in this manner. A variety of constructions are known to the art for providing such air dispersal and for providing so-called "low air loss" support. In a preferred embodiment, the bags are constructed in a generally airtight manner, and include a plurality of apertures, such as pinholes, placed therein to provide the desired airflow.

Referring now to FIGS. **12**A–D, therein is depicted head section **148** of overlay assembly **94**. Head section **148** includes three laterally disposed chambers **210**, **212**, **214**. Central chamber **212** is that section which will normally support the patient's head, and includes an air inlet **216** coupled to air channel **114** in support plate assembly **64** to facilitate independent control of the pressure in chamber **212**. Air inlet **216** will preferably couple, for example, through a length of tubing to a manual release connector member **102***b* which will engage a complimentary connector member **102***a*, (identified as item **530** in FIG. **4**). Outer head bolster chambers **210**, **214** each include air inlets **218**, **220** which couple in a similar manner to appropriate connectors **102***a* (see, for example, item **532** in FIG. **4**), on support plate assembly **64** to couple to flow channel **124** provide lateral support for the patient's head. Each chamber **210**, **212**, **214** preferably includes a plurality of transversely extending internal baffles **222**A, **222**B, **222**C in each chamber to maintain the shape of section **148** during inflation.

Referring now to FIGS. **13**A–C, therein is depicted torso section **150** of overlay assembly **94**. Torso section **150** includes a plurality, and preferably four, internal tubes or cells **151** extending generally across the width of torso section **150**. All four tubes are housed within the larger inflatable envelope **155** of torso section **150**. Each tube **151** is coupled to a connector **159** to facilitate coupling of the tube to a connector **102***a* on support plate **64**. Torso section **150** is that section which will provide percussion and vibration therapy to the patient through selective rapid inflation of each cell **151**. Torso section **150** includes a plurality of snaps to engage complimentary snaps **161** on adjacent sections. Section **150** also includes a coupling **153** to couple envelope **155**, through tubing, to a connector member **102***b*. (Such connector will couple, for example, to a complimentary connector as indicated at **533** in FIG. **4**).

Referring now to FIGS. **14**A–D, therein is shown a section of overlay assembly **94** as may be utilized for either of sections **152** or **154** for the seat and thigh portions of the patient's body, respectively. Each section **240** is divided into three distinct chambers **242**, **244**, and **246**. As previously described, outer chambers **242** and **246** serve as bolsters to assist in retaining a patient centralized upon overlay assembly **94**. Central chamber **244** is independently adjustable in pressure through an inlet **248** to establish optimal comfort and/or interface pressures for the patient.

Referring now to FIGS. **15**A–D, therein is depicted an exemplary cushion **157** as is used, in a set of three, to form foot section **156** of overlay **94**. Each cushion **157** includes three chambers **173**, **175**, and **179**. Outer chamber **173** and **179** form bolster chambers, while central chamber **175** will support the patient's feet. Each cushion **157** includes a plurality of snaps by which the cushion will couple to an adjacent cushion or section, or the fabric panel **90**. Each chamber includes a connector to facilitate fluid couping the support plate **64** in the manner previously described.

The use of separate cushion to support the patient's feet allows the feet to slip between the cushions to avoid localization of pressure on the back of the heel by allowing substantial support of the foot to come from the support of the bottom of the foot on a cushion; thereby reducing the likelihood of breakdown of the patient's skin.

Referring now to FIG. **29**, as stated previously, bed **20** is controlled through use of control panel **36** including a liquid crystal display **540** accompanied by a plurality of touch-sensitive membrane switches **539**. Switches **539** provide the data input medium for the microprocessor in control panel **36** controlling the functions of bed **20**. In one preferred implementation of the invention, control panel **36** includes a 32 bit Motorola 68331 microprocessor to control functions of bed **20**. Bed operating parameters are preferably contained within a 1 or 4 Mbit EPROM to facilitate program changes. A real time clock module provides time and date for software functions and preferably includes 114 bytes of non-volatile RAM for maintaining selected control panel data when power is removed.

Referring now to FIG. **16**, therein is depicted a block diagram of the electrical system **220** of bed **20**. Electrical system **220** includes control panel **36** as previously described. A power distribution board **228** provides an interface between control panel **36** and other control devices, including: the proportional valves **50** controlling airflow to each channel in the bed, a seat dump valve (described in reference to FIGS. **28**A–C); pressure transducers; blower; side guard position switches, head elevation sensors, and various other functions. To provide this interface, power distribution board **228** includes a microcontroller. Pressure feedback tubes (**56***a–j* in FIG. **7**) couple to pressure transducers on power distribution board **228** to facilitate moni-

toring and precise control of air pressures in cells in upper inflatable level **92** and lower inflatable level **74**. In addition to the proportional valve feedback, as previously described feedback of the main air pressure manifold is communicated to power distribution board **228** through a pressure feedback tube (**56***k* in FIG. **7**), to facilitate control of blower **40**. Some input signals to power distribution board are voltages which are then each converted to a digital signal and communicated to the microcontroller on the power distribution board **228**. Similarly, a digital to analog converter on the power distribution board receives digital signals from control panel **36** (and in particular from microprocessor **229** therein), and converts the signals into analog voltages to establish parameters, such as, for example, the proportional valve position (and resulting pressure output), and the blower speed.

Electrical box **230** receives input AC power and communicates that power both to the hydraulic controller circuitry which controls hydraulic functions of the bed, and also provides 24 to 27 volt DC current to operate blower **40**, a cooling fan, and further to voltage reducers providing 12 and 5 volts DC current for operation of electronics in bed **20**. A scale board **234** interfaces with a plurality of load cells (preferably 4 load cells) on bed **20** to facilitate monitoring a patient's weight. Cable interface board **236** provides a junction point for cables to interconnect the various control unit components, including those of the bed frame **26**, itself (see **231**, **233**).

Referring now to FIG. **17**, therein is depicted a flowchart **240** of the patient pressure baseline setup routine implemented trough control panel **36** by the microprocessor **229** therein. As can be seen, to ready the bed for a particular patient, inputs will be provided for the patient's height **242** and weight **244**. Based upon such inputs, control panel **36** determines initial baseline zone pressures **246** for the working cushions of lower support layer **74** and for overlay assembly **92**, based upon predetermined criteria. Such criteria are well-known in the industry, and are a matter of design choice. Once the predetermined baseline pressures are established, in each zone the pressure may be varied by the caregiver to define a pressure baseline specifically tailored to the individual patient. Typically, pressures of the working cushions will be equal within each cushion group **78**, **80**, **82**; and will typically range between 0 and 20 inches of water. Each of the preestablished zones in upper overlay assembly **94** will be adjusted to provide optimal interface pressure and patient comfort. To achieve this, once predetermined baseline pressures are determined **246**, for each zone and control panel **36** will communicate, through power distribution board **228** to operate proportional valves **50** to establish all cushion pressures at the predetermined baseline level **248**. At such time, the pressures may be individually customized through control panel **36** to vary pressures in individual zones **250**, or to adjust zone levels as necessary to achieve optimal patient comfort **252**. Once setup has been completed, any desired therapy may be selected **254**.

Referring now to FIG. **18**, therein is depicted a flowchart for blower pressure setup routine **256**. Where a therapy other than static support is selected for the patient, control panel **36** will adjust the blower pressure as appropriate. As can be seen in FIG. **18**, when rotation therapy is selected **258**, the blower pressure will be established to eight inches of water above the maximum zone pressure established during the setup procedure **240**. However, if relaxation therapy is selected **262** then the blower pressure will be established to six inches of above the maximum zone pressure established **264** during setup **240**. Where vibration therapy is selected **266**, percussion therapy is selected **268**, or a combination of vibration and percussion therapy is selected **274**, then in each circumstance, the blower pressure will be established to eight inches of water above the maximum zone pressure, **270**, **272**, respectively. In the absence of any therapy being selected **276**, then the blower pressure will be merely established to six inches of water above the maximum zone pressure and such level will be maintained during standard mode therapy **278**.

Referring now to FIGS. **19**A–F, therein is depicted flowchart of an exemplary rotation routine **280** for controlling rotation of a patient on bed **20**. Where rotation therapy was selected (see FIG. **17**) and the blower has been appropriately established (see FIG. **18**), then determined parameters regarding the speed of rotation in both a downward direction ("down slew rate") and an upward direction ("up slew rate") will be loaded **282** from predetermined data based on the patient's height and weight. In one preferred embodiment, the down slew rate will be approximately 0.5 inch of water/second; while the up slew rate will be approximately 0.1 inch of water/second. Subsequently, rotation of the patient to the left side will be initiated by decreasing the left working cushion pressure at the down slew rate, and by increasing the right cushion pressure at the same "up slew rate" while maintaining center cushion pressure at baseline **284**. During these changes, the pressures of overlay assembly **94** will remain essentially constant, while the pressures extending longitudinally down the entire length of the working cushions will preferably be varied at the preselected uniform rate. These changes will continue until a selected lower pressure is reached **285** in the (decreased pressure) left cushions. A determination is made if the rotation boost option has been selected **286**. If so, the center cushion pressure will be decreased **287** for a predetermined period, for example, fifteen seconds. The center cushion pressure will then be increased to equal that of the right side pressure **288** to complete rotation of the patient. Once the center working cushion pressure is equal to that of the right working cushion pressure, a pause is preferably included to allow the patient to remain in such position for a preestablished period of time **290**. After the expiration of the predetermined pause period is determined **292**, then control panel **36** initiates functions to center the patient, or to return the patient to a generally horizontal position. This function occurs: (1) by decreasing the center cushion pressure to the established baseline pressure at the predetermined "down slew rate"; (2) by decreasing the right side working cushion pressure to the established baseline at the up slew rate; and (3) by increasing the left side working cushion pressure to the established baseline at the up slew rate **294**. Once the baseline pressures are reached **296**, then the left side working cushion pressure will be increased to 1.5 times the baseline pressure **298**; and will subsequently then be decreased **300** until the left side working cushion pressure is again at the determined baseline **302**, thereby establishing true horizontal positioning of the patient. Again, a pause will preferably be effected **304** to maintain the patient in the horizontal position for a predetermined time period. Once the predetermined pause time **304** has expired **305**, then rotation of the patient to the right side will be initiated. This is done by decreasing the right working cushion pressure at the down slew rate while increasing the left working cushion pressure at the up slew rate while maintaining the center cushion pressure at baseline **306**. Once the desired pressure is reached in right working cushion **308** then a determination is again made if the rotation boost option has been selected **309**. If so, the center working cushion pressure will be

decreased for a selected time period **310**, and will then be increased in pressure to match that of left working cushion pressure **311**, thereby completing rotation, and pausing for a predetermined period **312**. Once the pause time has expired **314** the process will begin to again center the patient by decreasing the center working cushion and the left working cushion pressure to baseline at the down slew rate and the up slew rate, respectively, while increasing the right working cushion pressure to baseline at the up slew rate **316**. Once the baseline pressures are reached **318**, then the right side working cushion pressure will be increased to 1.5 times the baseline pressure **320** and then be decreased **322** until the baseline pressure is reached **324**, and a pause will then again be initiated at the center position **326**.

Referring now to FIG. **20**, therein is depicted a flowchart for a relaxation, or pressure relief, therapy routine **328**. Relaxation therapy will function by changing pressures within entire zones within overlay assembly **94**. When relaxation mode is entered, the chest zone and the seat zone will each be set to Atmospheric pressure **330**. After a pause for a predetermined time period, preferably 30 seconds, **332**; the chest zone and the seat zone will be returned to baseline pressure **334**. After another pause, again preferably for 30 seconds, **336**, the thigh zone and the foot zone will be decreased to atmospheric pressure **338**. After another pause, again preferably for 30 seconds, **340**; the thigh zone and foot zone will be returned to baseline pressure **342** and another pause will be initiated **344**.

Referring now to FIG. **21**, therein is depicted a flowchart for an exemplary routine for implementation of percussion therapy **346**. In the percussion therapy routine, determination is first made as to whether left rotation was selected **348**. If left rotation was selected, then the patient is rotated to the left in accordance with the flowchart of FIG. **18**A. Alternatively, if it is determined that right rotation was selected **350**, then the patient is rotated to the right in accordance with FIG. **18**C. Alternatively, of course, the patient may be merely retained in a horizontal position. Once the patient is in the desired position, the operator selected percussion frequency is input **356**. The boost solenoid (**480** in FIG. **31**) is then opened **358**, and after a delay of one half of the preselected percussion frequency **360**, the boost solenoid will be closed **362**. The vent solenoid (**481** in FIG. **31**) will then be opened, and after again a delay of one half of the preselected percussion frequency, the vent solenoid will be closed. The sequence will then be repeated **370** for the desired duration of the percussion therapy.

Referring now to FIG. **22**, therein is depicted a flowchart for an exemplary routine **372** for implementation of vibration therapy. Vibration therapy is essentially identical to percussion therapy, with the exception that the percussion will operate at approximately 1–5 cycles per second; while vibration will cycle at approximately 6–25 cycles per second. In the vibration therapy routine **372**, determination is first made as to whether left rotation was selected **374**. As with percussion, if left rotation was selected, then the patient is rotated to the left **376** in accordance with the flowchart of FIG. **18**A. Alternatively, if it is determined that right rotation was selected **378**, then the patient is rotated to the right **380** in accordance with FIG. **16**C. Alternatively, of course, the patient may be merely retained in a horizontal position. Once the patient is in the desired position, the operator-selected vibration frequency is connected to the power distribution board for controlling valve operation **382**. The boost solenoid (**480** in FIG. **31**) is then opened **384**, and after a delay of one half of the preselected vibration frequency **386**, the boost solenoid will be closed **388**. The vent solenoid (**481** in FIG. **31**) will then be opened **390**, and after again a delay of one half of the preselected vibration frequency **392**, the vent solenoid will be closed **394**. The sequence will then be repeated **396** for the desired duration of vibration therapy.

Referring now to FIG. **23**, therein is depicted a flowchart for combination percussion/vibration therapy **398**. If the combination percussion/vibration therapy mode is selected, then percussion therapy will be instituted in accordance with percussion routine **346** of FIG. **20**. At such time as the preestablished percussion duration has elapsed **402**, then vibration therapy will be instituted **404**, in accordance with flowchart **372** of FIG. **21**. Once the predetermined vibration therapy period has elapsed **406** then the patient will be returned to standard mode therapy **408**.

Referring now to FIG. **25**, therein is depicted an exemplary embodiment of a manual release connector **102**, as is described earlier herein, as being particularly useful for providing connections wherein hoses are to be coupled. Connector **102** includes a male member **420** and a female member assembly **422**. Male member **420** includes an extending portion **424** which includes two circumferential grooves **426**, **428**. Longitudinally outermost circumferential groove **426** houses an O-ring **430** by which to assure a sealing engagement with a complementary bore **434** within female member **422**. Second circumferential groove **428** is designed to align with a retaining plate **432** forming a portion of female member assembly **422**. Retaining plate **432** includes an elliptical aperture proximate an entrance to interior bore **434** of female member **422**. Retaining plate **432** is resiliently loaded, such as by a spring (not illustrated), such that in an unactuated condition, retaining plate **432** extends partially across the opening to internal bore **434**. When male member **420** is operably coupled to female member **422**, retaining plate will at such time engage circumferential groove **428** on male member **422** and thereby retain the two members in interlocked and operative relation to one another. Subsequent movement of retaining plate **432** will move plate **432** out of engagement with groove **428** and allow release of male member **420** from female member **422**. In most applications, male member **420** and female member assembly **422** will each include fluted connecters **436**, **438**, respectively, to facilitate coupling of hoses or similar apparatus to each member.

Referring now to FIGS. **28**A–C, therein is depicted an exemplary embodiment of a dump valve **439** appropriate for use with the present invention. As previously discussed, the purpose of dump valve **439** is to evacuate air from the seat section working cushion group **80** to facilitate patient ingress and egress. Dump valve **439** includes a valve block **440**, having three axially aligned valve sections **441**, **442**, **444**, which is operatively coupled, such as by bolts to support plate section **70**. Coupling of valve block **440** to support section **70** brings pairs of valve apertures **446***a, b*; **448***a, b*; and **450***a, b* into registry with corresponding apertures **452***a, b*; **454***a, b*; and **456***a, b*, respectively, in support section **70**. A rotating valve member **458** is operatively coupled, such as through shaft **460** and a slip clutch to an electric motor **462**, configured to selectively initiate rotation of valve member **458** in response to control panel **36** or another switch mechanism. Rotation of valve member **458** is approximately 90 degrees relative to valve blocks **440**, **442**, and **444**. Rotating valve member **458** includes three generally L-shaped passages (one depicted at **464** in FIG. **28**A) which are spaced such that in a first position (see FIG. **28**B) one leg **447** of the L-shaped profile interconnects pairs of apertures (for example **446***a* and *b;* while in a second position (see FIG. **28**A), the other leg **449** of the L

interconnects one of the apertures (for example **446***b*), with the corresponding vent aperture for that block (see **447**). Thus, when valve block **458** is in the described first position, air (for example, from outlet **452***a* in FIG. **4**) will enter an aperture (e.g., **446***a*), and will be communicated directly to an outlet aperture **446***b* coupled to working cushions of seat section cushion group **80** (i.e., cushions **180**) through the corresponding aperture (e.g., **452***b*) in support plate member **70**. However, upon actuation of motor **462** to rotate valve member **458** to the position depicted in FIG. **28**A, those working cushions (**180**) will be coupled (through aperture **452***b*), through segment **449** in valve member **458** to vent aperture (e.g., **451**) causing deflation of the connected working cushions.

Referring now to FIG. **30**, therein is depicted an exemplary assembly as may be utilized to provide fluid communication between support plate assembly **64** and portions of overlay assembly **94**. In particular, the depicted assembly is of a type as would be utilized to provide fluid communication between support plate assembly **64** and the bolster sections of foot cushions **157** (see FIG. **3**). A dome connector **502** is preferably adhesively coupled to support plate assembly **64**. A connector member **504** is threadably coupled to dome connector **502**. Connector member **504** may be fitting as manufactured by Colter Products Company of St. Paul, Minn., and identified as Part No. PLC240-04. A complimentary connector **506**, such as CPC fitting model PLDC170-06 (see FIG. **25**) will then be utilized to provide fluid communication through a length of appropriate tubing **508** to a T fitting **510**. Lengths of tubing **512** and **514** will then be utilized to provide further fluid communication. Specifically, tubing **512** will be connected through an elbow fitting **516** (such as CPC model PLCD230-06) and through another length of tubing **518** to a releasable coupling **520***a*. This releasable coupling may form an assembly, such as is depicted in FIG. **25**, which will be connected to either through a length of tubing (**522**, as depicted) or directly to an appropriate cell or chamber in overlay assembly **94**. Similar connections will be provided for each fitting **520***a–c*. Each tubing/fitting coupling may be secured through use of a clamp, such as a conventional hose clamp. When such a clamp is utilized, it is preferred that the clamp be covered with a protective material, such as shrink-tubing or another wrap material, to protect the surfaces of adjacent inflatable cells.

Referring now to FIG. **32**, therein is depicted an assembly **103** as is utilized to secure the outermost working cushions of each cushion group **78**, **80**, and **82** to support surface **64**, and to provide fluid communication to each cushion. Each cushion includes a fitting **103***b* having a circumferential retaining disc **542** extending therefrom. The lower end **541** of the fitting **103***b* will fit into a receiving bore **543** in a receptacle **103***a* adhesively secured to support plate assembly **64**. A retaining clip **546**, having generally C-shaped engagement apertures **548** and **550** will then be utilized to engage a circumferential groove **552** on receptacle **103***a* and circumferential disc **542** on fitting **103***b* to retain the two pieces in engaged relation.

As is apparent from the disclosure above, the preferred embodiment facilitates the establishing of desired interface pressures, coupled with a low air loss surface, and lateral support, or cradling, through use of a multi-zoned inflatable overlay; and further facilitates lateral positioning of the patient through use of a lower level of inflatable cells. Many modifications and variations may be made in the techniques and structures described and illustrated herein without departing from the spirit and scope of the present invention. For example, the lower inflatable level may be formed of one or more multi-celled units. Similarly, additional zones may be defined in either the upper or lower inflatable levels to achieve such degree of control as may be desired. Additionally, the lower inflatable level itself has utility for supporting a patient directly, without the intervening upper inflatable support layer (in which case portions of the lower inflatable layer may provide for air flow, as desired). Accordingly, it should be readily understood that the structures and methods described and illustrated herein are illustrative only, and are not to be considered as limitations upon the scope of the present invention.

What is claimed is:

1. A bed comprising:

a bed frame;

a support plate assembly mounted to said bed frame, said support plate assembly includes a plurality of plate sections wherein at least three sections are connected such that two generally transverse articulation points are formed to facilitate articulation of said plates;

a first pair of longitudinally extending, controllably inflatable air bags coupled to said plate assembly, said first longitudinal pair of bags laterally offset from one another and extending generally parallel along a first portion of the longitudinal length of said support plate assembly, one of said longitudinally extending bags is controllably inflatable generally independently of the other longitudinally extending bag of said first pair;

a second pair of longitudinally extending, controllably inflatable air bags coupled to said support plate assembly, said second longitudinal pair of bags laterally offset from one another and extending generally parallel and longitudinally offset from said first pair of longitudinal bags along a second portion of the longitudinal length of said support plate assembly, one of said second pair of longitudinally extending bags is controllably inflatable generally independently of the other longitudinally extending bag of said second pair;

a support layer positioned generally above said first and second pairs of longitudinal bags, said support layer including a plurality of controllably inflatable, transverse air bags, said transverse bags being grouped into a plurality of independently controllable pressure zones; and

a control assembly attached to the bed frame and operable to supply air selectively to said longitudinally extending bags and transverse bags to provide the patient at least one of a plurality of modes, said modes including a laterally rotating mode and a percussive mode.

2. The bed of claim **1**, wherein said support layer includes:

a head zone for supporting the head of the patient; and

at least one bolster zone extending along at least a portion of a side edge of the support layer, said bolster zone for maintaining the patient generally centered on the bed and substantially preventing patient contact with a portion of the bed frame.

3. The bed of claim **1** further including:

a percussion cell extending generally transversely across at least a portion of the width of the frame and aligned beneath the torso area of the patient, and

said control assembly selectively operable to inflate and deflate said percussion cell whereby the percussion mode is provided to the patient.

4. The bed of claim **1** wherein at least a portion of the transverse air bags of the support layer are low air loss air bags.

5. A therapeutic bed for supporting a patient, comprising:

a bed frame assembly;

a support surface assembly mounted to said bed frame assembly, said support surface assembly includes a plurality of plate sections, wherein at least three sections are connected such that two generally transverse articulation points are formed to facilitate articulation of said plates;

a first pair of longitudinally extending inflatable air bags coupled to said support surface assembly, said longitudinal air bags of the first pair laterally offset from one another and extending generally parallel along a first portion of the longitudinal length of said support surface assembly, each longitudinally extending air bag being alternatively inflated of the other longitudinally extending air bag to lift a portion of the patient to laterally rotate the patient;

a second pair of longitudinally extending inflatable air bags coupled to said support surface assembly, said second pair of longitudinal air bags laterally offset from one another and extending generally parallel and longitudinally offset from said first pair of longitudinal air bags along a second portion of the longitudinal length of said support surface assembly, each longitudinally extending air bag of said second pair of air bags being alternatively inflated of the other longitudinally extending air bag of the second pair to lift a portion of the patient to laterally rotate the patient;

an inflatable upper layer positioned above at least a portion of said first and second pairs of longitudinal air bags, said upper layer including a plurality of generally transversely extending air bags, at least some of said transverse bags are inflatable independently of others of said transverse air bags of said inflatable upper layer, said upper layer further including a plurality of separately inflatable zones formed from at least a portion of the air bags of the upper layer;

a percussion cell assembly extending generally transversely across at least a portion of the width of the bed and aligned beneath the torso area of the patient, said percussion cell assembly being adapted to be selectively inflated and deflated to provide a percussion mode; and

a programmable electronic controller assembly mounted to said bed frame assembly and selectively operable to control the pressure in said longitudinal air bags, said zones of the upper layer and said percussion cell assembly whereby the patient may be provided a plurality of operating modes.

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